GIS MAPPING AND ANALYSIS OF AIRCRAFT NOISE AT CAPE TOWN INTERNATIONAL AIRPORT

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AUTHOR'S DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

ABSTRACT

The noise produced by aircraft during operations around airports represents a serious social, technical, economic and environmental problem which is only going to get worse as air traffic volumes increase. Rapid urbanisation, development encroachment and poor planning in the past have resulted in noisy airport runways being situated too close to residents' living space. Rapid industrial growth and lack of funding exacerbate noise problems in developing countries. Moreover, developing countries and especially South Africa tend to have moderate climates and open-window living, which makes insulation an ineffective solution to the noise problem.

This study aims at employing GIS to establish the potential noise exposure of various sensitive land use categories and population groups in the noise-controlled area at Cape Town International Airport. Firstly, options for the demarcation of a noise-controlled area were evaluated. Thereafter, incompatible land uses and priority areas for land use compatibility projects were identified and recommendations made for urban renewal projects for these areas. Lastly, the noise-exposed population were profiled according to vulnerability characteristics and vulnerable groups identified and located.

A recommendation was made that Cape Town International Airport set up an interactive map-based website to disseminate information to the public about noise and any other important issues concerning the airport. An Internet GIS application would empower citizens by providing them with a dynamic and interactive tool for improved public participation and a better understanding of the potential environmental and socio-economic effects of the airport. Noise complaints could also be investigated through the website and prompt feedback given to the communities complaining about aircraft noise.

At the local community level where people are being annoyed every day and night resulting in negative health effects, the problem of aircraft noise demands urgent attention, and measures should be put in place to reduce vulnerability to noise and improve the overall quality of life of noise-weary residents.

Keywords: aircraft noise, noise mapping, noise-controlled area, noise contours, land use compatibility, noise exposure

OPSOMMING

Die geraas veroorsaak deur vliegtuie by lughawens bied ernstige sosiale, tegniese, ekonomiese en omgewingsprobleme, wat net erger gaan raak namate vlugverkeer toeneem. Snelle verstedeliking, ontwikkelings-oorskryding en swak beplanning in die verlede het veroorsaak dat raserige aanloopbane te naby aan mense se leefruimte gebou is. Vinnige industriële groei en 'n tekort aan befondsing vererger geraasprobleme in ontwikkelende lande. Bowendien het ontwikkelende lande, en veral Suid Afrika, 'n matige klimaat en oop-venster-leefwyse wat isolering 'n oneffektiewe oplossing maak vir die geraasprobleem.

Hierdie studie het ten doel om GIS te gebruik om die potensiële geraas blootstelling van sensitiewe grondgebruike en bevolkingsgroepe in die geraas-kontrole area by Kaapstad Internasionale Lughawe vas te stel. Eerstens is opsies vir die afbakening van die geraas-kontrole area geëvalueer. Daaropvolgend is onversoenbare grondgebruike en prioriteitsareas vir grondgebruik-versoeningsprojekte geïdentifiseer en aanbevelings gemaak vir stedelike vernuwingsprojekte vir hierdie areas. Laastens is 'n profiel daargestel van die geraas-blootgestelde bevolkings volgens kwesbaarheidskenmerke en kwesbare groepe is geïdentifiseer en hul ligging aangedui.

'n Voorstel is gemaak dat Kaapstad Internasionale Lughawe 'n interaktiewe kaart-gebaseerde webwerf in werking moet stel om inligting oor geraas- en ander belangrike probleme in verband met die lughawe beskikbaar te stel vir die publiek en ander belanghebbendes. 'n Internet-GIS toepassing sal mense bemagtig deur hulle te voorsien van 'n dinamiese en interaktiewe meganisme wat sal lei tot beter gemeenskapsdeelname en ook 'n beter begrip van die potensiële omgewings- en sosio-ekonomiese uitwerking van die lughawe. Klagte oor geraas kan ook deur die webwerf hanteer en ondersoek word, en verder hulp verleen word deur vinnige terugvoering aan die gemeenskap wat die klagtes gelê het.

Op plaaslike gemeenskapsvlak, waar mense elke dag en nag geïrriteerd raak en waar dit dan kan lei tot negatiewe gesondheidsinvloed, sal die probleem van vliegtuiggeraas dringend aangespreek moet word, en stappe geneem word ten einde kwesbaarheid van inwoners teenoor vliegtuiggeraas te verminder. Dit sal dan lei tot die algehele verbetering van die lewensgehalte van geraas-moeë inwoners.

Sleutelwoorde: vliegtuiggeraas, geraaskartering, geraas-kontrole area, geraaskontoere, grondgebruik versoenbaarheid, geraasblootstelling

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LIST OF ACRONYMS

ACNIM	Aircraft Community Noise Impact Model
ACSA	Airports Company of South Africa
ADR	Aeroporti di Roma
CSIR	Council for Scientific and Industrial Research
CTIA	Cape Town International Airport
DNL	Day-Night Average Sound Level
dBA	Sound pressure level in decibels, using frequency weighting network A
FAA	Federal Aviation Administration
GIS	Geographical Information Systems
INM	Integrated Noise Model
NASA	National Aeronautics and Space Administration
NI	Noisiness Index
SAA	South African Airways
SABS	South African Bureau of Standards
SADT	South African Department of Transport
USA	United States of America

CHAPTER 1: A CRESCENDO OF NOISE

> *Noise is the most impertinent of interruptions for it not only interrupts our thoughts but disperses them.*
> Schopenhauer, Eighteenth-century Philosopher.

1.1 AIRCRAFT NOISE AS AN ENVIRONMENTAL PROBLEM

'The same factors that brought us air and water pollution in crisis proportions, namely increasing population, urbanization, industrialization, technological change and the usual relegation of environmental considerations to a position of secondary importance to economic ones, have brought us a crescendo of noise' (Anthrop 1973:17). Moreover, the advent of the internal combustion engine increased the number of noise sources not only on the surface of the earth, but also in the sky. Aircraft noise began to be a major problem with the great surge in air transportation which followed World War II. The introduction of jet airplanes, which came into widespread use by the end of the 1950's, led to a second revolution in aviation. The advent of supersonic transport created the third major escalation in aviation noise (Bugliarello et al. 1976).

The economic vitality of jet service triggered explosive growth both in the air transportation industry and in those cities and industries it serviced. As airports grew in size and importance, the areas adversely affected by aviation noise also expanded (U.S. Department of Transportation 2000a). Rapid urbanisation, development encroachment and poor planning in the past have resulted in airport runways being situated too close to people's living rooms, so to speak.

Passenger air traffic worldwide is expected to grow in future and, with the air traffic volume rising, air transport's environmental impacts will also increase. The Federal Aviation Administration (FAA) in the USA (United States of America) believes that aircraft noise remains the number one environmental problem facing international civil aviation policy today (U.S. Department of Transportation 2000b).

1.2 IMPACT OF AIRCRAFT NOISE ON POPULATION AND PROPERTY

The World Health Organisation defines health as 'the state of complete physical, mental and social well-being and not merely the absence of disease' (Abeyratne 1994:240). Tempest (1985) is of the opinion that noise obviously diminishes wellbeing, so in that sense health is adversely affected, while Abeyratne (1994) believes that even the slightest noise which disturbs rest, sleep or relaxation is a positive health hazard.

Since the 1960's numerous studies have found aircraft noise linked to:

- auditory problems: Intense noise from aircraft can cause temporary and/or permanent damage to the human hearing process.
- speech interference: Aircraft noise makes spoken communication more difficult to achieve. Quality speech communication is obviously important in the classroom, office and industrial settings. The disruption of leisure activities such as listening to the radio, television, music and conversation gives rise to frustration and irritation (Kryter 1994).
- sleep interference: Aircraft noise can be a much greater disturbance to sleep than other noises. Bugliarello et al (1976) found that the number of people awakened by aircraft near London's Heathrow Airport is about 50% higher than the number awakened by other noises.
- task interference: The effect of noise on human performance of tasks is a complicated subject that is under continuous study. Cunniff (1977:38) established that 'noise does affect complex tasks, but is more likely to reduce the accuracy of work than to reduce the total quantity of work.'
- annoyance: This is the most prevalent effect of aircraft noise. For people living in the vicinity of airports, aircraft noise causes far more annoyance and disturbance than does any other form of transportation noise. This annoyance leads to negative community reaction (Tempest 1985).

The impact of aircraft noise on land use and on the community depends on many factors. These include the type of aircraft, the number of aircraft movements, operating procedures, time of day, seasonal or meteorological phenomena, as well as local factors such as the specific type of land use, type of buildings occupied, distance from the airport, ambient noise levels and community attitudes (South African Department of Transport 1999).

The impact of aircraft noise on property values is a complex subject with studies showing that aircraft noise can affect property prices both negatively or positively. A study by the U.S. Department of Commerce (1985) showed that aircraft noise decreased the value of residential property located around airports. The research found negative effects from aviation noise, with effects ranging from a 0.6% to 2.3% decrease in property value per decibel increase of cumulative noise exposure.

Tomkins et al. (1998) investigated the extent to which proximity to an airport is capitalised into residential property prices. It was suggested that circumstances may exist where the positive attributes of airport proximity, such as improved access and employment opportunities, may be more highly valued by local residents than the negative externality effects, like aircraft noise.

1.3 AIRCRAFT NOISE IN SOUTH AFRICA

The problem of aircraft noise pollution knows no political or social boundaries and affects developed and developing countries. According to Mato & Mufuruki (1999), noise pollution is an often forgotten environmental problem that is steadily growing in developing countries. Unavoidable and rapid urbanisation in developing countries often surges ahead of proper planning and drives the poor and less developed sectors of the population into ever-closer contact with the industrial and commercial sectors where high noise nuisance levels traditionally occur. Rapid industrial growth and lack of funding exacerbate noise problems in developing countries. Moreover, developing countries and especially South Africa tend to have moderate climates and open-window living, which makes insulation an ineffective solution to the noise problem (Johnston 1989).

According to the South African Department of Transport (1999:64), 'there is growing concern in South Africa that the environmental impact of airports is unacceptable and inadequately controlled' and that 'many communities are displaying growing resistance to the increasing noise pollution from airports located in residential and commercial areas.' Authorities claim that the uncontrolled increase in noise pollution from the airports is sterilising major areas of developable land, to the extent that the airports are sometimes viewed as having more negative than positive impacts (South African Department of Transport 1998). Another major concern is the fact that many of the new airlines that are entering South Africa are using old, noisy Chapter 2 aircraft that are not acceptable in other countries (South African Department of Transport 1998).

Many of the existing airports in South Africa are located inside built-up urban areas where considerable surrounding development has taken place, not all of which takes the noise contours of the airports into account (South African Department of Transport 1999). Cape Town International Airport is a prime example of where progress in aviation went ahead of urban planning.

1.4 THE NOISE PROBLEM AT CAPE TOWN INTERNATIONAL AIRPORT

Cape Town International Airport (CTIA) was developed in the early 1950s on the farm Belhar which was located outside the city boundary at that time. It is now the most important airport of the Western Cape Region and the second busiest in South Africa, handling 16,7% of the total international and 30,3% of the total domestic passengers (Airports Company of South Africa 2000). It is connected with more than 20 airlines connecting the Western Cape with all the important airports in South Africa and with most hubs of Europe and some important gateways in North America, South America and the Far East. Passenger traffic is expected to more than triple in the next 15 years, increasing from 5 million passengers in 2003, to 6,5 million by the year 2004, and to 14 million by 2015 (Airports Company of South Africa 2003). The growth rates projected for Cape

Town are higher than the growth forecast for Johannesburg and globally higher than the expected world traffic growth in the medium term (Airports Company of South Africa 2000).

Despite speculation, CTIA will not be relocated elsewhere, as this is an unaffordable option. The costs of new buildings, terminals and runways, land acquisition and transportation and bulk service infrastructure would be too high (Airports Company of South Africa 2001). CTIA serves as an investment node in the economically depressed Metro South East, creating jobs and opportunities for investment which would be limited if the airport were to be moved to a more isolated site. Airports Company of South Africa (2001:5) maintains that 'it is unlikely that Cape Town will have sufficient market depth to sustain two international airports or even a transition from one to another.'

Air traffic is going to increase and therefore an additional runway is proposed and this will increase the amount of potential noise. It is, therefore, necessary to strengthen the management thereof by planning correctly in potentially affected regions. One way this can be achieved is by designating a "controlled area", which the Provincial Noise Regulations define as a piece of land designated by a local authority where the aircraft noise exposure level is above 65dBA, projected for 15 years (South African Department of Transport 1999).

1.5 RESEARCH AIMS AND OBJECTIVES

The aim of this study is to employ a Geographical Information System (GIS) to establish the potential noise exposure of various sensitive land use categories and population groups in the noise-controlled area at CTIA, demarcated according to the Yearly Day-Night Average Sound Level (DNL) noise contours. DNL contours were used as this research was done before the publication of SANS 10117 and 10103 which use Yearly Equivalent Continuous Day-Night Level contours.

Specific objectives are to:

1. Demarcate a "controlled area" based on the 65DNL noise contour for the year 2015, by identifying on the ground the extent of this area.
2. Build a GIS database of land use types in the noise-controlled area and to classify land-use types according to noise sensitivity levels.
3. Identify priority areas for land use compatibility projects i.e. the most sensitive areas.
4. Profile the exposed population in the noise-controlled area by demographic, physical and socio-economic vulnerability characteristics.
5. Synthesise the analysis by overlaying noise intensity levels with land use and population data to identify incompatible land uses and vulnerable population groups.

1.6 GIS AND THE AIRCRAFT NOISE PROBLEM

> *"We are just witnessing the beginnings of the widespread use of GIS in airports around the world."*
> (Rowe & Caraway 1998:14)

Airports have been compared with small cities in that they need similar infrastructure managed by many of the same departments as a city. In addition, airports face many similar environmental challenges associated with day-to-day operations. The ability of GIS to help manage infrastructure and environment makes it a very useful tool for airport management. McNerney (1994) maintains that the major expenses at airports today are the cost of the infrastructure and the mitigation of environmental problems.

The potential applications where GIS can be used at airports can, therefore, be divided into three areas, namely:

- infrastructure management,
- environmental analysis or management, and the
- intrinsic GIS capability such as geographic analysis, display of raw, queried or analysed data and database error checking.

The environmental analysis or management applications related to aircraft noise include management of noise complaints, noise contour calculation, analysis of changes in noise contours, noise monitoring programs and management of off-airport properties such as noise mitigation programs.

The GIS can be used as a planning tool to map noise contours and identify areas of unacceptable noise levels for sound-proofing programs resulting in time and cost savings. Rowe & Caraway (1998:14) view GIS as an 'important decision-making tool' which can be used to study alternatives for future expansion of airports by showing noise impacts from various proposed runway scenarios.

Harder (1998:63) comments that 'studying the noise impact of flight operations on surrounding communities is a classic application of GIS thinking; it has a spatial component, a temporal component and is best communicated with a map.'

1.7 STUDY AREA DEMARCATION

Figure 1.1 indicates the location of CTIA and the noise- affected areas surrounding it. The airport is located approximately 20km east of the city centre and is connected to the city by the N2 freeway which runs from Cape Town through to Port Elizabeth. The total area of the airport is approximately 900 ha and it is surrounded by variant-status, but mostly low status, residential development and some light industrial development in its immediate vicinity.

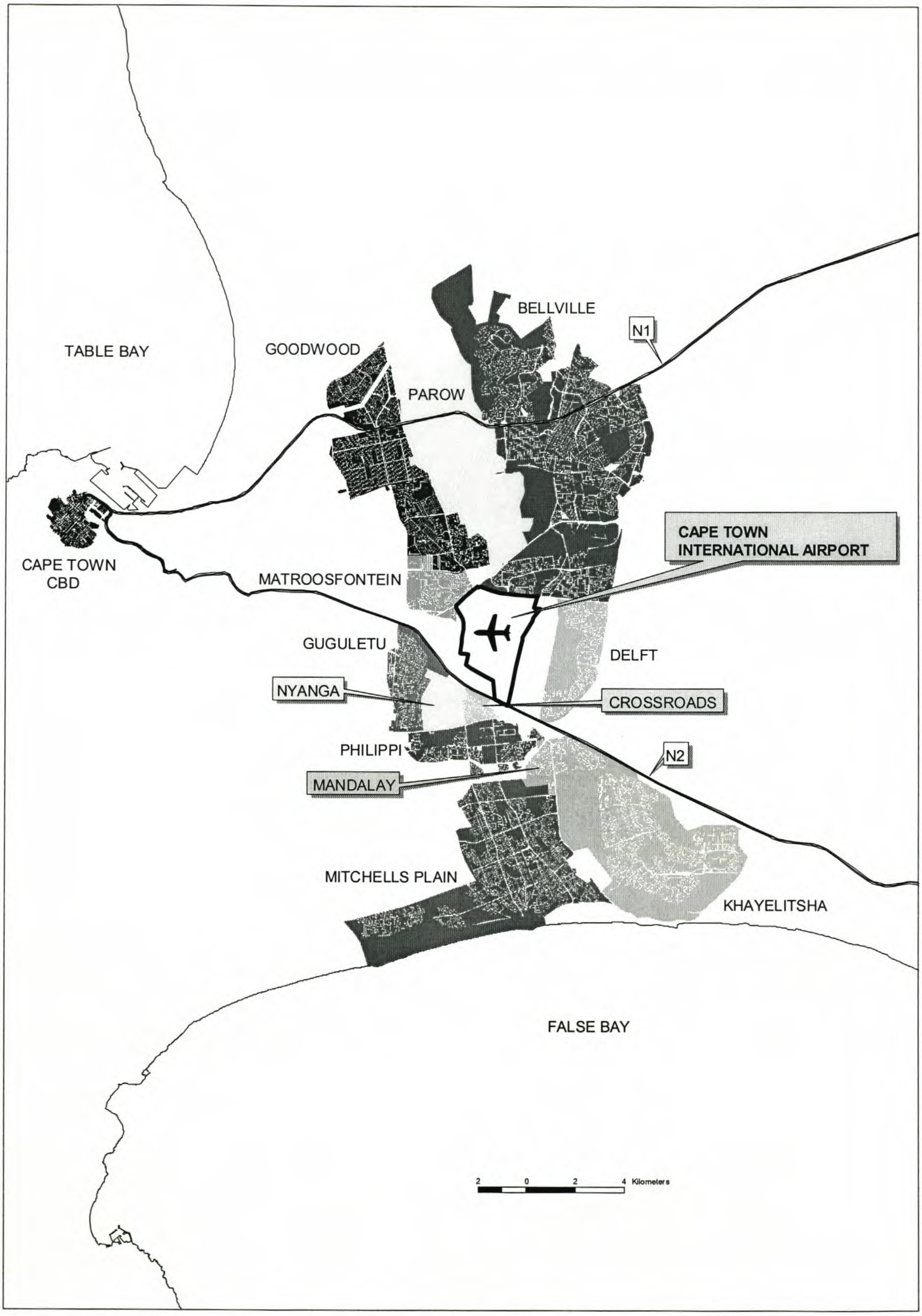

Figure 1.1 Location of Cape Town International Airport

1.8 RESEARCH FRAMEWORK

The research framework depicted in Figure 1.2 indicates the logical and sequential research steps followed in this thesis to realize the study aims and objectives as they are reported in the various chapters. It makes clear that the noise-controlled area around the airport is the pivotal central construct. The first step is therefore to demarcate this area and here various options are created through a combination of various spatial data layers. The noise contour layer (data base provided for 65DNL) is combined with the official spatial unit (erven, street blocks, enumerator areas) and Euclidean distance parameter buffer (distances of 100m and 200m) layers to produce and demonstrate six possible demarcation scenarios. Once demarcation has been completed, two sets of noise impact manifestations are considered for a particular demarcation option in separate compatibility analyses. Firstly, land use and zoning types are considered by using spatial data obtained from local authorities. Secondly, utilizing Census 1996 data at enumerator level identifies vulnerable population groupings. These analyses are dealt with in the last two consecutive empirical chapters.

Data sources utilised were mostly secondary in nature and obtained from various primary sources:

- Noise contours were supplied by private consultants Chittenden Nicks & De Villiers and ADR Planning, who were responsible for their primary modelling and computer generation;
- Cadastral boundaries, land use and zoning information were provided by Tygerberg Administration in GIS format;
- Population data were gleaned from the summarised Census 1996 data bank managed by the Department of Geography and Environmental Studies, University of Stellenbosch.

1.9 REPORT FRAMEWORK

The rest of the thesis is divided into four sections, the first three corresponding with the five main objectives of the research and the final section being the synthesis. The first objective was to demarcate a "controlled area" for CTIA and this is thus the focus in Chapter 2. Within this chapter, aircraft noise modelling is discussed and the aircraft 'footprint' at CTIA indicated. The demarcation options are compared and then evaluated in terms of their advantages and disadvantages. Chapter 3 deals with the second and third objectives, which are related to land use compatibility in the noise-controlled area. Land use types were classified according to noise sensitivity levels and the priority areas (the most sensitive areas) identified. In Chapter 4 the focus then switches to the population affected by noise and Objectives four and five. These include profiling the noise-exposed population according to vulnerability characteristics and identifying vulnerable groups. The final chapter summarizes the results and gives recommendations and suggestions for further research.

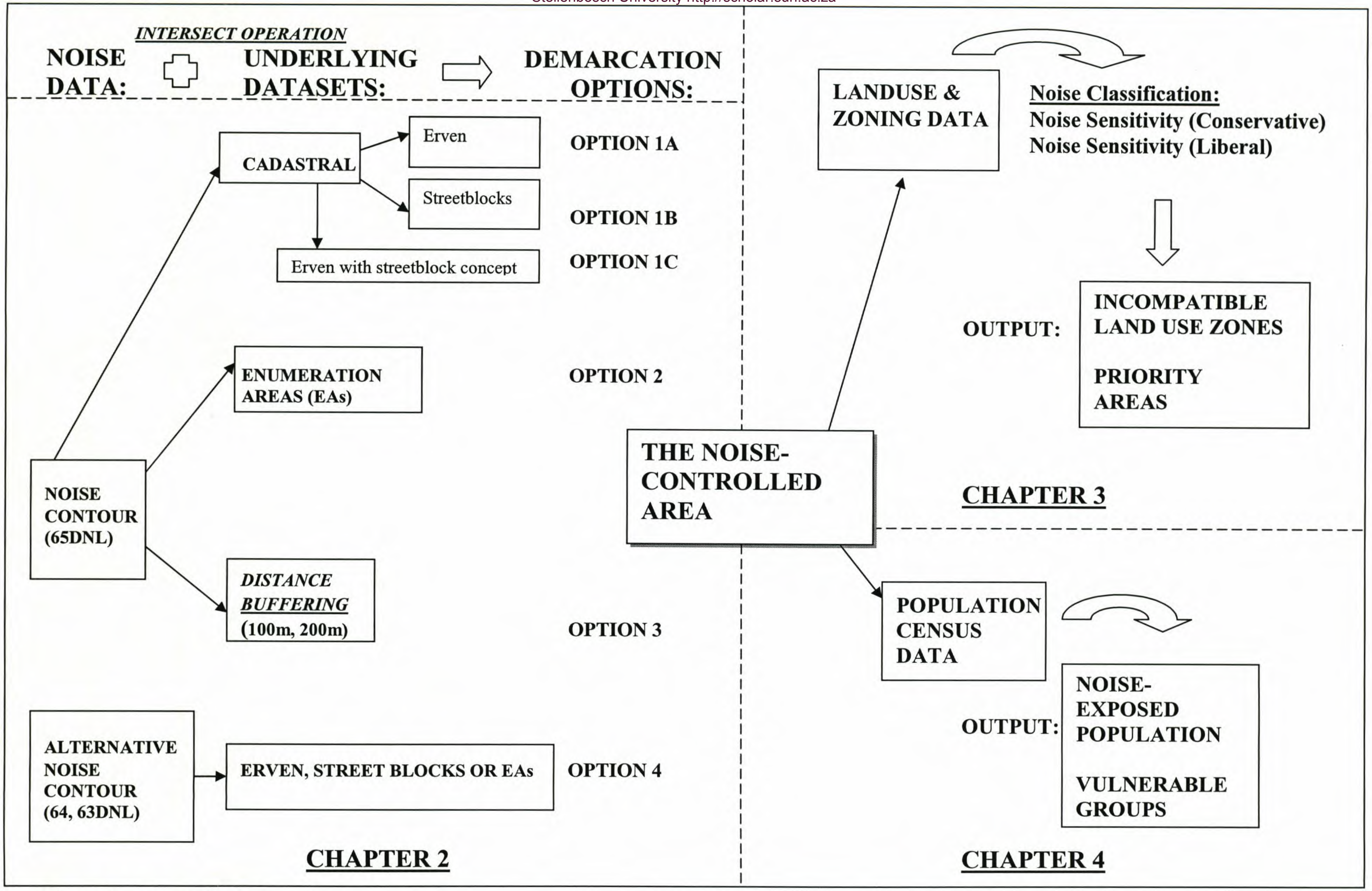

Figure 1.2 Research framework

CHAPTER 2: DEMARCATION OF AFFECTED AREAS USING AIRCRAFT NOISE MODELLING

This chapter introduces the concept of aircraft noise modelling in general and then more specifically discusses aircraft noise modelling in South Africa. The process of demarcating a noise "controlled area" follows, concluding with the evaluation of the demarcation options.

2.1 AIRCRAFT NOISE MODELLING IN GENERAL

The need for aircraft noise modelling and a description of what constitutes an aircraft noise model are discussed to begin with. The two noise models, the Integrated Noise Model and the Aircraft Community Noise Impact Model are introduced as well as the aircraft noise descriptor, the Day-Night Average Sound Level. Lastly, the noise contours, which are the output of the noise model, are reviewed.

2.1.1 Why model aircraft noise?

Many airports compute noise exposure directly through the use of noise monitoring systems at sites on and around the airport, but this method is expensive, time consuming and quantifies only the current impact of noise exposure. Acoustical interference from other noise sources such as roads and railways can also be an obstacle to reliable noise monitoring and, thus, microphones have to be sited carefully and measurements made during poor weather rejected (Rhodes & Ollerhead 2001).

To calculate the future noise impact of air traffic growth and to perform "what if" studies, noise can be quantified through computer-based simulation models. These models are predictive and descriptive tools capable of depicting noise propagation and quantifying the impacts on surrounding communities. They are capable of integrating airport geometry, noise levels, atmospheric conditions, and aircraft performance characteristics into a single, unified picture of noise exposure patterns in and around airports. Aircraft noise models can also provide a comparison of predicted and measured sound levels through a process called model validation (Transportation Research Board 1997).

2.1.2 What is an aircraft noise model?

An aircraft noise model consists of a group of equations that describe the relationship among various factors contributing to the intensity and distribution of aircraft noise. Typically, a model has three major components:

- The core equations - computational algorithms for calculating the sound level produced, on average, by a specific type of aircraft performing a specific operation and for calculating cumulative noise levels by all the types of aircraft using a given airport;
- An aircraft data base containing the noise and performance characteristics of each type of aircraft operating at a given airport;
- Additional inputs for environmental factors affecting sound levels (typically airport elevation, temperature, atmospheric pressure, wind direction and speed, runway gradient, etc.) as well as operational information such as traffic mix, runway usage, and flight tracks (Transportation Research Board 1997).

2.1.3 The Integrated Noise Model (INM) and the Aircraft Community Noise Impact Model (ACNIM)

The FAA in the USA has developed the Integrated Noise Model (INM) for evaluating aircraft noise impacts in the vicinity of airports. The INM has been the FAA's standard tool since 1978 for determining the predicted noise impact in the vicinity of airports. The model utilises flight track information, aircraft fleet mix, standard and user-defined aircraft profiles and terrain as inputs and produces noise exposure contours. It includes built-in tools for comparing contours and utilities that facilitate easy export to commercial geographic information systems. The model also calculates predicted noise at specific sites such as hospitals, schools and other sensitive locations.

The INM is but one of several aircraft noise models that have been developed over the past 20 years. The Aircraft Community Noise Impact Model (ACNIM), which combines several existing aircraft noise models with a full-featured geographic information system and with flight trajectory optimisation software, has been developed by Wyle Laboratories for the National Aeronautics and Space Administration (NASA). The ACNIM enhances the FAA's INM by providing a more detailed population and land use analysis of noise-impacted communities surrounding airports. It produces optimised flight trajectories that serve the purpose of minimising community noise impacts. The model helps the user visualise how alternative scenarios would increase or decrease the number of people affected within each noise level contour by enabling the user to make clear distinctions between populated and unpopulated areas when performing population and housing counts. The end result is a smarter population impact analysis (Stusnick et al. 1998). Figure 2.1 diagrammatically shows how GIS integrates into the INM and the ACNIM.

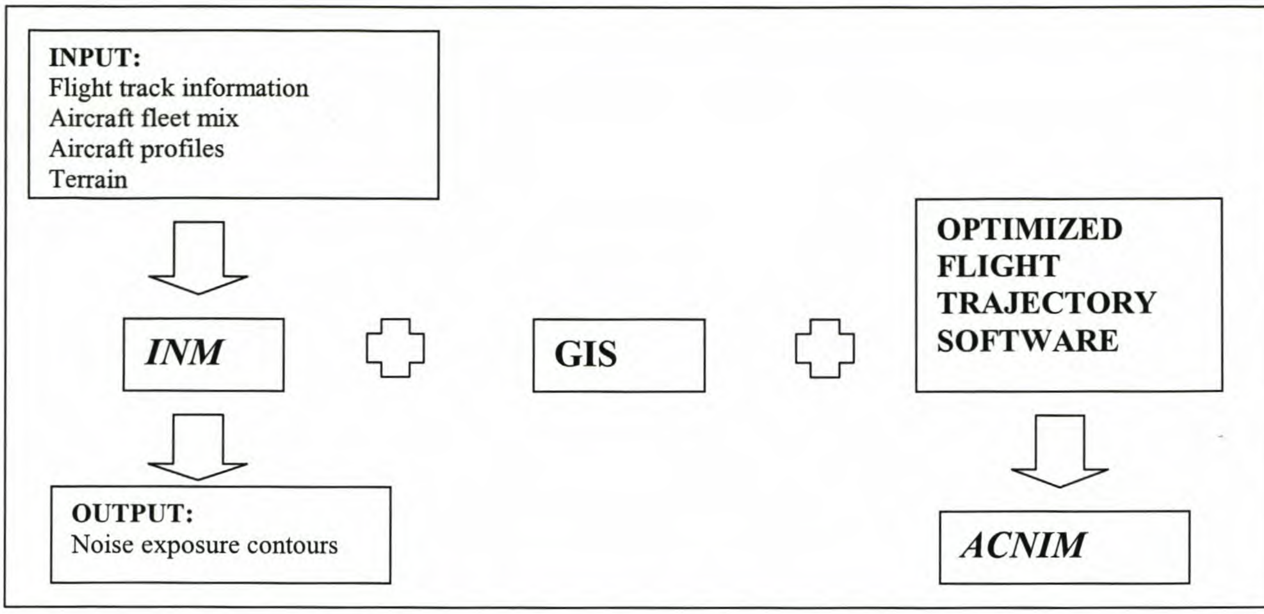

Figure 2.1 The relationship between the INM, the ACNIM and GIS

While flight track information, aircraft and locational information feed into the INM to produce noise contours, GIS and the addition of optimised flight trajectory software to generate community impact scenarios with planning implications can enhance this output in ACNIM.

2.1.4 The DNL airport noise metric

Many noise metrics exist and the INM can produce contours in many different measures, but the descriptor of choice for airport noise assessment and land use compatibility studies is the Day-Night Average Sound Level (DNL). DNL is the 24-hour average sound level, in decibels, obtained from the accumulation of all events with the addition of a 10 decibel penalty to sound levels in the night from 22h00 to 07h00. The weighting of night-time events accounts for the usual increased interfering effects of noise during the night, when ambient levels are lower and people are trying to sleep (U.S. Department of Transportation 2000a).

In 1981, the FAA formally adopted the DNL as the single system for determining exposure of individuals to airport noise. The US Department of Transport (2000a) indicates that the DNL is the most widely accepted descriptor for aviation noise because it:

- is a measurable quantity;
- is simple to understand and use by airport planners and the public who are not familiar with acoustics or acoustical theory;
- provides a simple method to compare the effectiveness of alternative airport scenarios;
- correlates well with the results of attitudinal surveys of residential noise impact;
- allows quantitative comparison of noise from various sources within a community and
- increases with the duration of noise events and takes into account the number of noise events for the full 24 hours in a day, both important to people's reaction.

Not all countries use the DNL as airport noise descriptor and there is research suggesting that it can be insensitive (Mestre 2001), difficult to measure and misunderstood by the community. Green & Fidell (1991) found that DNL measurements did not correlate well with people's attitudes of noise impact and reported annoyance in noise surveys.

Potentially confusing is the difference between the noise metrics DNL and dBA. The dBA metric can be defined as a single event sound level metric used to describe peak noise levels of aircraft flyovers (Federal Interagency Committee on Urban Noise 2001a). The DNL metric, which is a cumulative average metric, is derived from measurements made in dBA (Airports Company of South Africa 2000). It is important to remember the logarithmic nature of dBA, which means a large range of sound intensities can be compressed into a manageable scale with a range of 0 dBA, at which sound can barely be heard, to about 120 dBA, at which sound can cause pain from excessive exposure. A large commercial jet aircraft, when 500 feet overhead, can generate about 115 dBA (Airports Company of South Africa 2000).

2.1.5 The INM output: noise contours

The output of the INM is a set of spatial noise contours of equal sound exposure level. The spatial noise impact of a single aircraft is often referred to as a *noise footprint*. The cumulative spatial effects of a series of individual aircraft operations over a specified time are generally referred to as *noise contours* (Transportation Research Board 1997). The INM computes spatial noise levels at finite points on a grid, which are then plotted and interpolated to create noise contours. Figure 2.2 indicates how an average annual aircraft flight path is constructed using noise contours.

Noise contours provide the important guidance necessary to make sensible land use zoning and planning decisions, but there are a number of factors to be taken into consideration when they are used in decision-making.

Firstly, noise contours are fuzzy boundaries. A discussion of the concepts 'boundary' and 'fuzziness' is, thus, necessary. A boundary is something that separates two things. Hadzilacos (1996:248) maintains that 'when the things are geographic entities or phenomena in two-dimensional space, then the boundary is a 'line' on either side of which some property of interest has different values... . Administrative boundaries, set for reasons of social necessity and often the subject of GIS, tend to be crisply defined, well known and stable. Natural boundaries, like noise contours on the other hand, tend to be fuzzy, uncertain and often move with time.' According to Schneider (1996:142), 'Fuzziness describes the vagueness of objects which have an extent, but which inherently do not have a precisely definable border.' Consequently, it is important not to see noise contours as rigid boundaries when decisions are made.

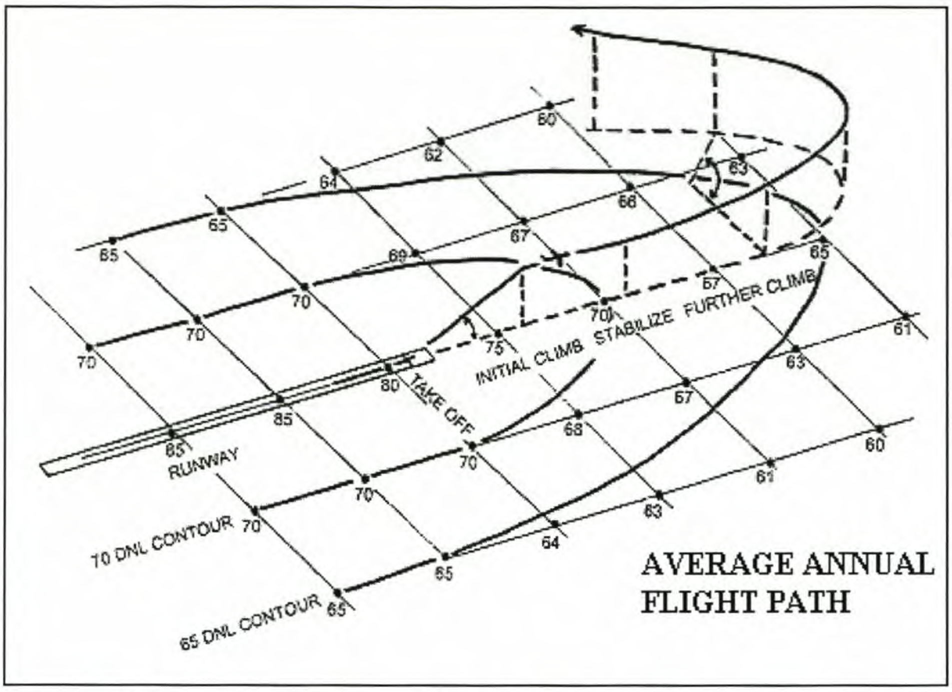

Figure 2.2 Construction of an aircraft flight path using noise contours

Source: Airports Company South Africa 2000:5.8

Secondly, noise contours become fuzzier as the exposure level decreases and more discrete and sharp as the exposure level increases. This is because INM's ability to accurately compute noise exposure degrades rapidly beyond and thus below, the 60DNL contour line, due to complex aircraft interactions and routings that occur at this distance from the airport. For example, a 55DNL contour would be rather fuzzy, while a 75DNL line would be sharply in focus (Rhodes & Ollerhead 2001).

Thirdly, the accuracy of noise contours can be challenged when local conditions are not similar to the standard field conditions adopted in the DNL method, and the area exhibits atypical geographical characteristics. Pereira Filho, Braaksma & Phelan (1995) found that many complaints arose when noise contours were implemented as rigid guidelines regardless of factual local evidence.

2.2 NOISE MODELLING IN SOUTH AFRICA

This section deals with aircraft noise modelling in South Africa and more specifically at Cape Town International Airport. The noise contours for the years 2000 through 2030 are displayed and examined.

2.2.1 The South African Noisiness Index

During the 1960s the government realised the need to predict noise caused by aircraft operations around all major airports in South Africa (Airports Company South Africa 2001). In 1966 an interdepartmental committee was established and entrusted with the task of investigating the problem of noise around airports (Robertson 1989). This committee sponsored an investigation by the Council for Scientific and Industrial Research (CSIR) working in collaboration with the South African Bureau of Standards (SABS), and assisted by several government departments, local authorities and South African Airways (SAA). The investigation showed that there was no unified international approach to aircraft noise modelling at that stage and also no 'international model'. The decision was then taken to develop a uniquely South African model, the Noisiness Index (NI). The results were published in three documents called Codes of Practice SABS 0115, SABS 0116 and SABS 0117 (Airports Company South Africa 2000). The Noisiness Index is a deterministic model which uses noise emission values from specific aircraft types to calculate noise emission on a reference grid. For each node on the grid, the noise exposures due to individual aircraft movements are calculated to arrive at the NI of that point.

In recent years the need has become evident to revise the South African model, mainly due to the difficulty in maintaining and modernising the input database of noise emission values. Also the NI cannot readily be integrated into or compared with noise caused by other sources, and according to the Airports Company South Africa (2000) has become outdated. In May 2003 the SABS drafted a new National Standard, the SANS 10117:2003 which states that the INM is the noise prediction model of choice and the noise descriptor to be used is the Yearly Equivalent Continuous Day-Night Level contour ($L_{Rdn,\,y}$). A major difference between DNL and $L_{Rdn,\,y}$ is the time weighting used. $L_{Rdn,\,y}$ has a night weighting from 22h00 to 06h00 whereas DNL is from 22h00 to 07h00 (Standards South Africa 2003).

2.2.2 The situation at Cape Town International Airport

During the 1970s, the first issues regarding noise were being raised at the present Cape Town International Airport (CTIA), the first noise contours were plotted and the need to plan for a second runway was recognised. In 1986 the Provincial Planning Department adopted the 70NI noise contour line at CTIA as the limit for residential and other development. This was a contentious decision as the SABS 0117 limits residential development to 65 NI. Based on the low number of aircraft using the airport at that stage, the 70NI contour line was inside the land designated for airport purposes in the Urban Structure Plan of 1988. This allowed residential development to encroach almost onto the boundary of the airport (Airports Company South Africa 2001).

The South African Department of Transport (2002) considers the regular calculation of noise contours essential. The only basis for recalculation of noise contours has been the SABS recommendation that this should be done every five years. Since no formal legal requirements were stipulated for calculation and recalculation of noise contours, this did not take place for most of the airports in South Africa. Noise contours at CTIA were calculated for the years 1977, 1978, 1984 and 1990, using the NI Noise Prediction Model. The 1997 contours were calculated using the equivalent A-weighted sound level metric (Laeq), which describes long term or cumulative noise exposure over any duration, in the INM. ADR Planning (ACSA's international partners) produced the first DNL contours for the CTIA Master Plan update in 2000, using version 6.0a of the INM. These contours were produced to compare the environmental impact of the different scenarios identified for the configuration of the new runway in the long-term master plan of the airport (Airports Company South Africa 2000).

2.2.3 Noise contours from 2000 to 2030

Figure 2.3 indicates how the noise contours simulated for CTIA are affected by the increase in total number of daily aircraft movements and the phase out of old and noisy Chapter 2 aircraft (See footnote in Table 2.2). The shape of the contours depicting the year 2000 conditions and the before phase out conditions is similar, except for the obvious increase in extent of the latter due the increase in total number of daily movements. The most significant change in noise contour shape and extent occurs after the phase out of Chapter 2 aircraft. Table 2.1 shows that the total number of daily aircraft movements is the same, but the area affected in each noise zone is less than half the area affected before the phase out.

Table 2.1 Effect of Chapter 2 aircraft phase out, runway configuration and number of daily aircraft movements on the extent of the noise zones around Cape Town International Airport

AIRPORTS COMPANY OF SOUTH AFRICA DATA			OWN DATA				
REFERENCE YEAR	RUNWAY CONFIGURATION	TOTAL NUMBER OF DAILY AIRCRAFT MOVEMENTS	NOISE ZONE AREA (IN HA)				
			55-75 DNL	60-75 DNL	65-75 DNL	70-75 DNL	75 DNL
2000	Existing site and runway configuration	180	5796	2668	1233	537	212
2008 (ADR Planning incorrectly assumed the phase out of Chapter 2 aircraft to start in 2008. Phase out actually starts on 1 Jan 2004.)	Existing site and runway configuration	335	8989	4090	1845	866	355
2009 (ADR Planning incorrectly assumed all Chapter 2 aircraft to be phased out by 2009 while the actual date for the end of phase out is 31 Dec 2010.)	Existing site and runway configuration	335	3090	1320	507	207	93
2015	Additional runway added with open V configuration	418	3781	1619	549	255	123
2030	Additional runway added with open V configuration	680	6101	2662	988	398	176

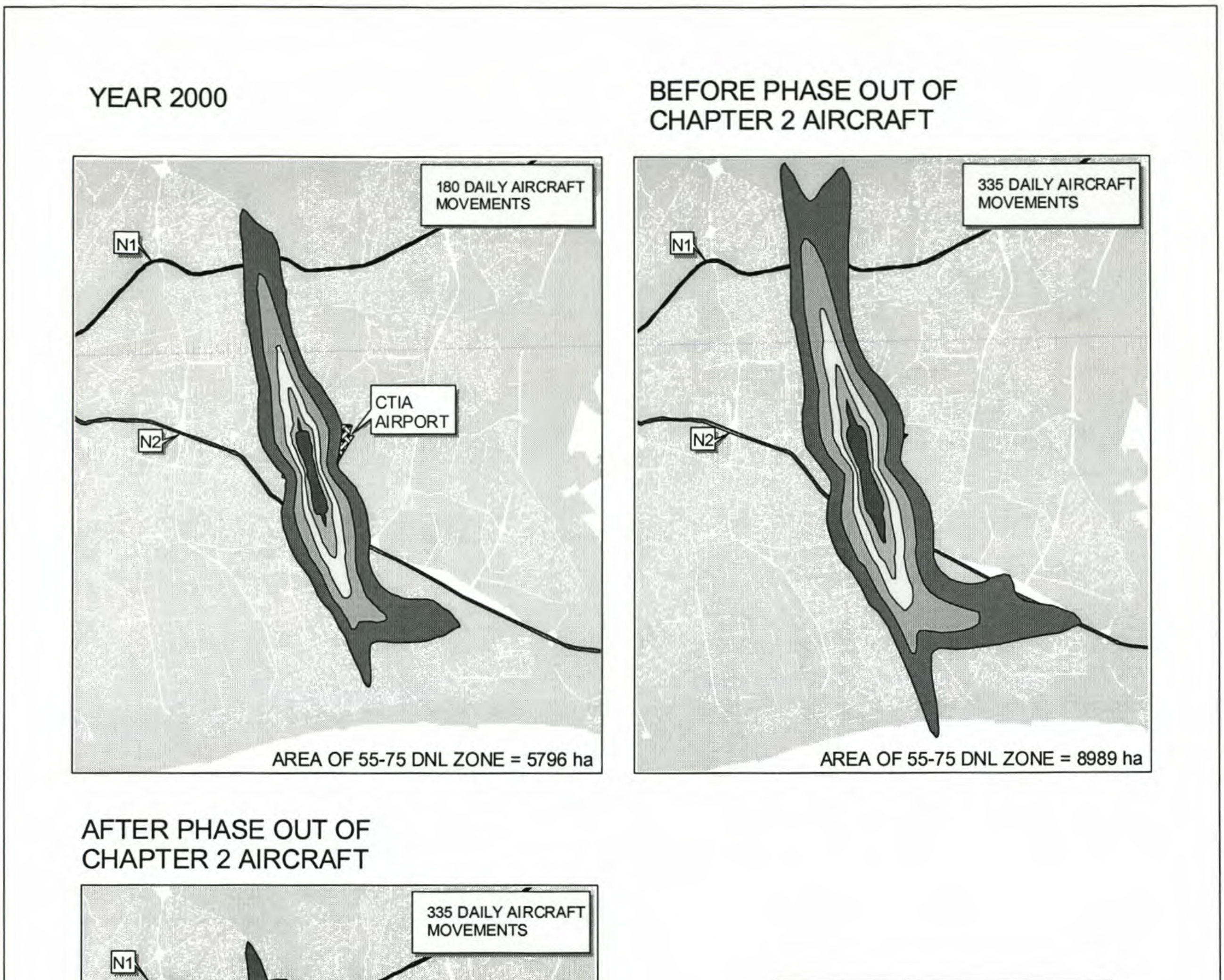

Figure 2.3 Effect of increase in the number of daily aircraft movements and Chapter 2 aircraft phase out on the noise contours around Cape Town International Airport

ADR Planning incorrectly assumed the before and after phase out dates of the Chapter 2 aircraft to be the year 2008 and the year 2009. Therefore, the total number of daily movements was calculated for those years. The dates for phase out of Chapter 2 aircraft in South Africa have been under revision for some time but have subsequently been decided on in the updated National Policy for Aircraft Noise and Engine Emissions due for imminent release. They are as follows: No additional Chapter 2 aircraft will be permitted in South Africa after 1 January 2003. The phase out starts on 1 January 2004 and lasts for a period of seven years. By 31 December 2010 all Chapter 2 aircraft must be phased out and 100% of the fleet must consist of Chapter 3 aircraft (South African Department of Transport 2002). Table 2.2 demonstrates how the aircraft traffic mix will change over the next 30 years.

In 2015 the spatial pattern of the noise contours will change considerably from the previous set shown in Figure 2.3, due to the addition of a new runway built with the Open V configuration. Figure 2.4 indicates that as the total number of daily aircraft movements increases a much larger area is affected by aircraft noise, in particular the area south of the N2. Table 2.1 shows how the 55-75DNL noise zone will reach over 6000 hectares by 2030.

Table 2.2 Aircraft traffic mix over the next 30 years

REFERENCE YEAR	AIRCRAFT TYPE	AIRCRAFT TRAFFIC MIX
Year 2000	Not certified	9%
	Chapter 2	24%
	Chapter 3	54%
	Other	13%
	Total	100%
2008 (ADR Planning incorrectly assumed the phase out of Chapter 2 aircraft to start in 2008. Phase out actually starts on 1 January 2004.)	Not certified	9%
	Chapter 2	24%
	Chapter 3	54%
	Other	13%
	Total	100%
2009 (ADR Planning incorrectly assumed all Chapter 2 aircraft to be phased out by 2009 while the actual date for the end of phase out is 31 December 2010.)	Not certified	0%
	Chapter 2	0%
	Chapter 3	88%
	Other	12%
	Total	100%
2015	Not certified	0%
	Chapter 2	0%
	Chapter 3	86%
	Other	14%
	Total	100%
2030	Not certified	0%
	Chapter 2	0%
	Chapter 3	92%
	Other	8%
	Total	100%

*Chapter 2 aircraft are subsonic jet aircraft, noise certified before 6 October 1977.
*Chapter 3 aircraft are subsonic jet aircraft, noise certified after 6 October 1977 and produce 50% less noise on takeoff.

Source: Adapted from Airports Company of South Africa 2000

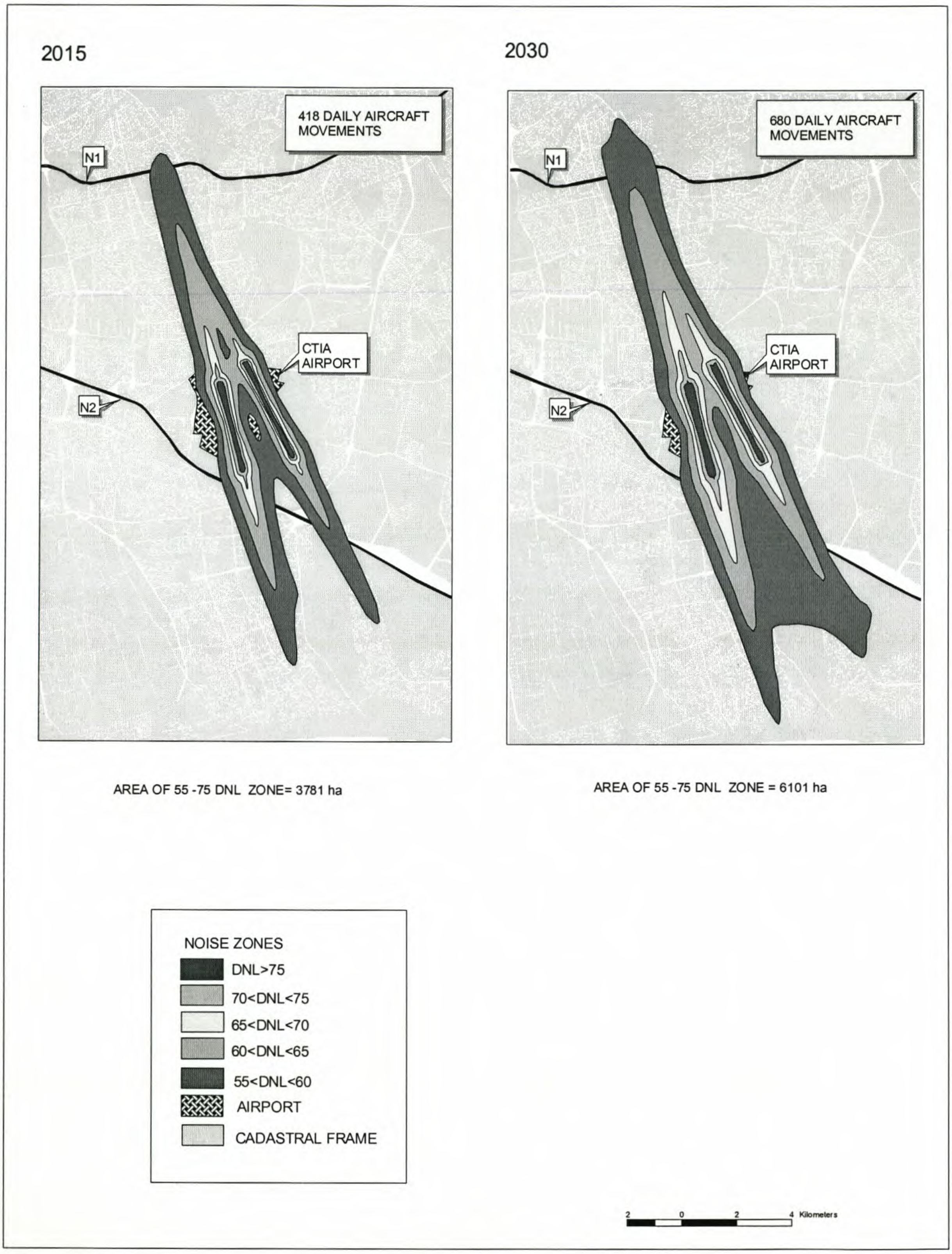

Figure 2.4. Effect of increase in the number of daily aircraft movements and the additional runway on the noise contours around Cape Town International Airport

2.3 DEMARCATION OF A NOISE "CONTROLLED AREA"

Aside from these mechanistic sound contour demarcations, planning purposes require the demarcation of a noise "controlled area" around airports. The demarcation of a noise "controlled area" is assessed in terms of the legal implications, international application examples, the technical process and the options for demarcation.

2.3.1 Legal implications

Section 25 of the Environment Conservation Act (Act 73 of 1989) provided for noise regulations to be formulated. These regulations were published in 1992 and the SABS Code of Practice 0117-1974 was incorporated into the Environment Conservation Act. In 1998 the Provincial Minister of Environmental Affairs of the Western Cape repealed the Noise Control Regulations of 1992 by publishing revised regulations for the Western Cape in the Provincial Gazette. The Provincial Noise Control Regulations empowers a local authority to declare a "controlled area'. It is, therefore, the responsibility of the City of Cape Town to declare a "controlled area" around CTIA. In section 2(f) of the Noise Regulations a "controlled area" is defined as 'a piece of land designated by a local authority where the aircraft noise exposure level is above 65DNL, projected for 15 years' (Airports Company South Africa 2001:5.5). Note the use of DNL contours as this was prior to publication of SANS 10117:2003.

Various attempts were made to demarcate such an area around Cape Town International Airport but nothing has been demarcated or implemented to date. According to Krynauw (2002:3), 'A very clear legal framework is required to ensure compliance [by the local authorities] in future… .Within a "controlled area" [the City of Cape Town] may impose any appropriate conditions when granting permissions or exemptions in terms of the Regulations. This may include conditions related to the insulation of homes or other buildings in the conditions of establishment for a new township… . [The City of Cape Town] may also require acoustic screening measures in new buildings or when extensions to buildings are considered. This will be applicable to **new** educational, residential, hospital, church or office buildings within the "controlled area". If a building is erected without the acoustic screening measure as imposed by [the City of Cape Town], a fine not exceeding R20 000 may be imposed.'

2.3.2 International application

Declaring a noise "controlled area" using the 65DNL noise contour is one way of protecting areas in the vicinity of an airport against noise. Two applications using similar concepts, the 'aircraft noise overlay district' and the 'airport environs overlay zoning district', have been implemented in the USA and will be discussed in this section. Both cases entail demarcating a 'noise overlay district' with the aim of protecting the health, safety and welfare of persons and property in the vicinity of the airport by regulating development and land use within noise sensitive areas and airport hazard areas. The district also aims to ensure compatibility between the airport and surrounding land uses and protects the airport from encroachment of incompatible land uses.

In Florida, an 'Aircraft Noise Overlay District' facilitates proper land use planning in the area surrounding the Orlando International Airport and the Orlando Executive Airport. Five Aircraft Noise/Land Use Control Zones are used which are based on a projection of future noise environments arising from aircraft flight operations:

- Zone A: ≥ 75DNL contour
- Zone B: 70-75DNL contour
- Zone C: 65-70DNL contour
- Zone D: The composite limits of the 60DNL contour and the 80dBA contour to the 65DNL contour.
- Zone E: The composite of the limits of the 55DNL and the 75dBA contour to the composite limits of the 60DNL contour and the 80dBA contour (Federal Interagency Committee on Urban Noise 2001a).

The boundaries of the 'Aircraft Noise Overlay District' coincide with the outer boundary of Zone E. When determining the location of noise zone boundaries, the authorities used the land use restriction standards associated with the more stringent zone when the boundary line crossed a land parcel (Federal Interagency Committee on Urban Noise 2001a).

At Walker Field Airport near Grand Junction in Colorado the 'Airport Environs Overlay Zoning District' is used consisting of four sub-districts. The sub-districts represent different levels of expected noise impact and hazard from aircraft. If any parcel is within more than one sub-district, the more restrictive sub-district determination applies.
The sub-districts are as follows:

- Area of Influence (Sub-district A): An area surrounding the airport impacted on or influenced by proximity of the airport, either by aircraft overflight, noise and/or vibrations.
- Noise Zone (Sub-district B): Includes the area within the 65DNL - 70DNL noise-exposure area.
- Critical Zone (Sub-district C): A rectangular-shaped zone located directly off the end of a runway's primary surface, beginning two hundred feet from the end of the pavement, which is critical to aircraft operations as shown in the airport master plan.

- Clear Zone (Sub-district D): A triangular-shaped zone located directly off the end of a runway's primary surface, beginning two hundred feet from the end of the pavement, which is clear of all above-ground obstruction or construction. The length is determined by the use of the runway (City of Grand Junction Colorado 2002).

Critical evaluation identifies a number of good points in the 'Aircraft Noise Overlay District' method of protecting the area surrounding the airport. Firstly, the entire sensitive area surrounding the airport is included in the five zones of the district and not just the area greater than the 65DNL noise contour as is the case in the South African noise "controlled area". Secondly, the use of composite contours for demarcating zones D and E, based on land use controls for two noise metrics, DNL and dBA, is interesting. The dBA metric is a single event sound level metric and single event metrics can be useful when evaluating mitigation strategies in detail and when comparing operational changes like noise abatement departure procedures where the DNL metric can be insensitive (Mestre 2001).

The Walker Field 'Airport Environs Overlay Zoning District' raises a number of questions. Firstly, how is the Area of Influence demarcated? No contour line is suggested to form the boundary of this district. Secondly, why does the Noise Zone only include the area within the 65DNL – 70DNL contours and not the area within the greater than 70DNL zone? Thirdly, is it necessary in terms of protecting the public to distinguish between the area envisaged by the critical and clear zones?

2.3.3 Demarcation process

The demarcation method as applied in this study, and especially the GIS principles employed and the data used are considered in the following section.

2.3.3.1 Demarcation methods and GIS principles

Two GIS methods of demarcation were used in this research: intersection and buffering. Intersection can be defined as the topological integration of two spatial datasets that preserves features which fall within the spatial extent common to both input datasets, while buffering is described as the process whereby a zone of fixed size is created around a point, line or polygon (Prescott 1994). ArcView GIS version 3.2 was used to do a *select by theme selection* which selects the features of the active themes that intersect with the features of the theme specified, and in the buffering option, selects features within a certain distance of the theme specified. Note that Arcview's implementation of intersect using *select by theme* implies that at least one point is common to both input datasets and therefore selects more than the area common to both input data sets with no boundary clipping.

2.3.3.2 Data used in the demarcation process

Two spatial datasets are needed to do the demarcation process: the aircraft noise contours and an underlying dataset of spatial units with practical utility. The question is which noise contours to intersect or buffer with which underlying dataset? From the definition of the "controlled area" given above, it can be construed that the noise contour line to use for demarcation is the 65DNL line for the reference year 2015. This implies planning for an era after the addition of an open-V dual runway system and the phase out of Chapter 2 aircraft. For the underlying datasets, it was decided to use both cadastral and enumerator area data as this data is readily available under most conditions.

2.3.4 Demarcation rules and options for the "controlled area"

Selecting demarcation methods are not straightforward. Practical difficulties and differences arise when different spatial frameworks and GIS methods are employed for demarcation. They may differ according to the spatial units (erven, street blocks, enumerator areas) forming the spatial framework or the GIS method (intersection, buffering) employed. The six different options selected to demarcate the "controlled area" here, are evaluated in this section and the differences are summarised in Table 2.3.

2.3.4.1 Option 1A: Cadastral Erven and the 65DNL contour

The rule for this option is that all the property units (cadastral erven) that intersect with the polygon formed by the 65DNL noise contour are selected. The reason why the units are intersected with the polygon created by the 65DNL instead of the 65DNL line is that all units fully contained inside the area of the polygon, as well as those intersecting the polygon, are included. The resulting area is indicated on Figure 2.5 and, as can be seen on Table 2.3, this option generates the smallest affected area (below 2000 ha) of all the options.

Table 2.3 Options for "Controlled Area" demarcation

OPTION	DATASET	METHOD	CONTOUR LINE (DNL)	AREA (HECTARES)	DATA UNIT
Option 1A	Cadastral Erven	Intersection	65	1879	520
Option 1B	Cadastral Street blocks	Intersection	65	2245	31
Option 1C	Erven & Street Blocks	Intersection	65	2317	1954
Option 2	Enumerator Areas	Intersection	65	2872	12
Option 3	Cadastral Erven	Buffering (100m)	65	2000	1373
Option 3	Cadastral Erven	Buffering (200m)	65	2116	2448
Option 4	Cadastral Erven	Intersection	64	1952	1061
Option 4	Cadastral Erven	Intersection	63	2008	1847
Option 4	Cadastral Erven	Intersection	62	2589	3144
Option 4	Cadastral Erven	Intersection	61	2733	5985
Option 4	Cadastral Erven	Intersection	60	3193	9585

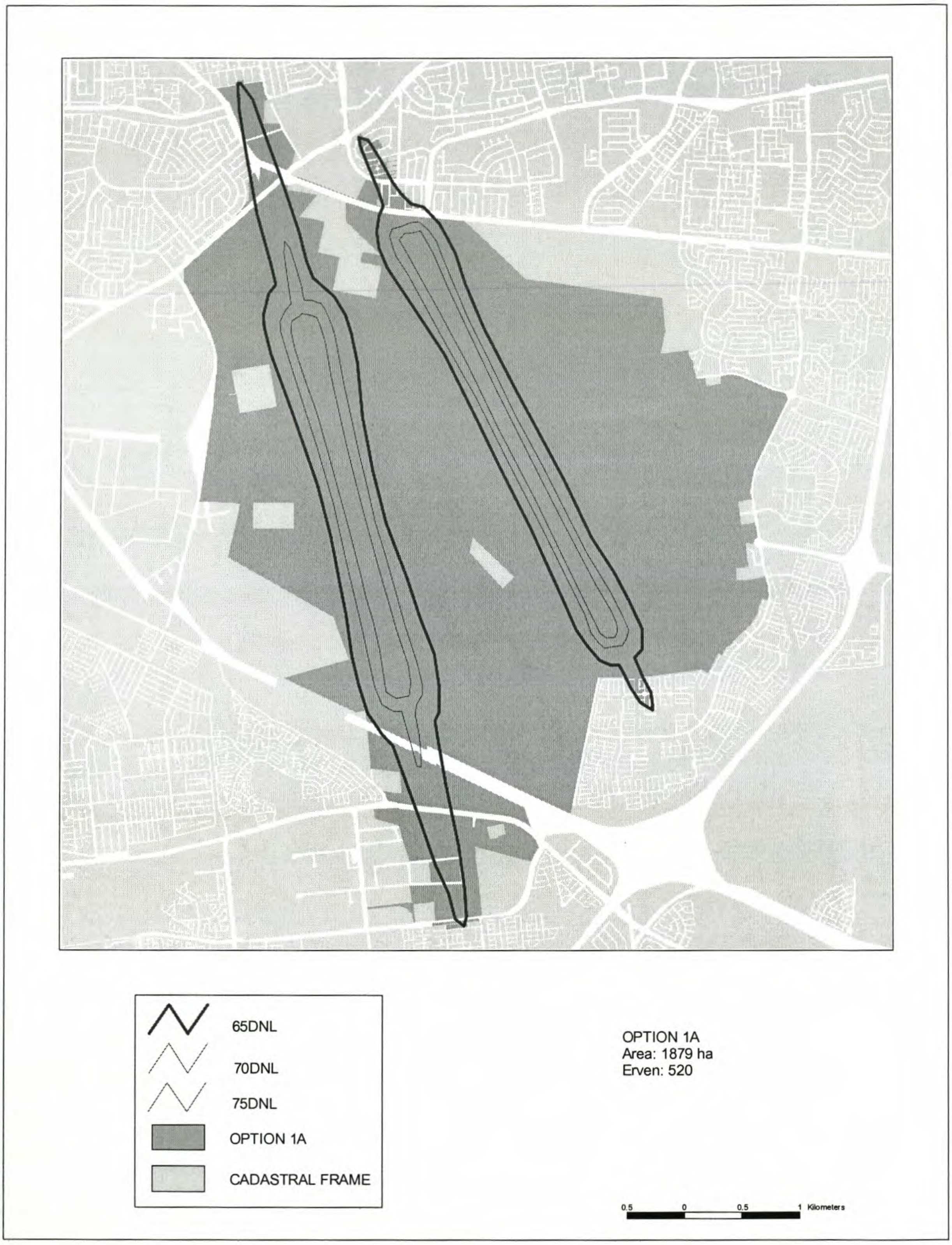

Figure 2.5. Controlled areas: Option 1A

2.3.4.2 Option 1B: Street blocks and the 65DNL contour

This option has the same rule as the previous option except that all the street blocks that intersect with the polygon formed by the 65DNL noise contour are selected. The reasoning behind this option is that streets form good boundaries for demarcation, creating complete units and in some cases a more uniform shape. If the street pattern in the area was in a grid this would occur, but due to the shape of the 2015 noise contours and the curved streets in the vicinity of the airport the area created was jagged. The difference in size from option 1A can be seen in Figure 2.6, and the size of the affected area increases by about 360 ha.

2.3.4.3 Option 1C: Erven with street block concept and the 65DNL contour

The rule for this option is that all cadastral erven which intersect with the area created by the street block option are selected. This option is used if the data is required in cadastral erven, but the concept of street blocks is desired. This creates the largest area of the three options discussed so far and includes almost four times as many erven as Option 1A. Figure 2.7 and Table 2.3 demonstrate these differences – again an increase of some 400 ha.

2.3.4.4 Option 2: Enumerator Areas and the 65DNL contour

If demographic data are required to assess noise impact on people, then census enumerator areas can be used which change the resolution of the underlying data set. Therefore, the rule is that all enumerator areas that intersect with the polygon formed by the 65DNL noise contour are selected. This option creates a very large area as indicated in Figure 2.8 and Table 2.3. If the area produced by Option 2 is converted to property units more than 20 times as many erven as in Option 1A are selected. The area is now some 1000 ha larger than Option 1A and 500 ha larger than Option 1C.

2.3.4.5 Option 3: Buffering the 65DNL polygon

The reasoning behind this option is that, due to the fuzzy nature of the boundary, noise exposure cannot be acceptable on the one side of the contour line but a nuisance on the other. Therefore, a buffer zone at a specified distance from the line is created. The rule states that all erven, enumeration areas or street blocks within a certain distance from the polygon formed by the 65DNL noise contour are selected. A buffer of 100m and 200m was created around the cadastral erven polygon. Figure 2.9 shows the significant difference between the area created by a 100m buffer, a 200m buffer and Option 1A. A disadvantage of this option is that the buffer boundaries do not take the shape of the noise contours into account. The 100m buffer almost reaches the 60DNL contour, and in some places the 200m buffer reaches the 55DNL contour to the west and east of the airport where the contours are closer together. Figure 2.10 zooms in to the area north of the airport where this situation can be seen.

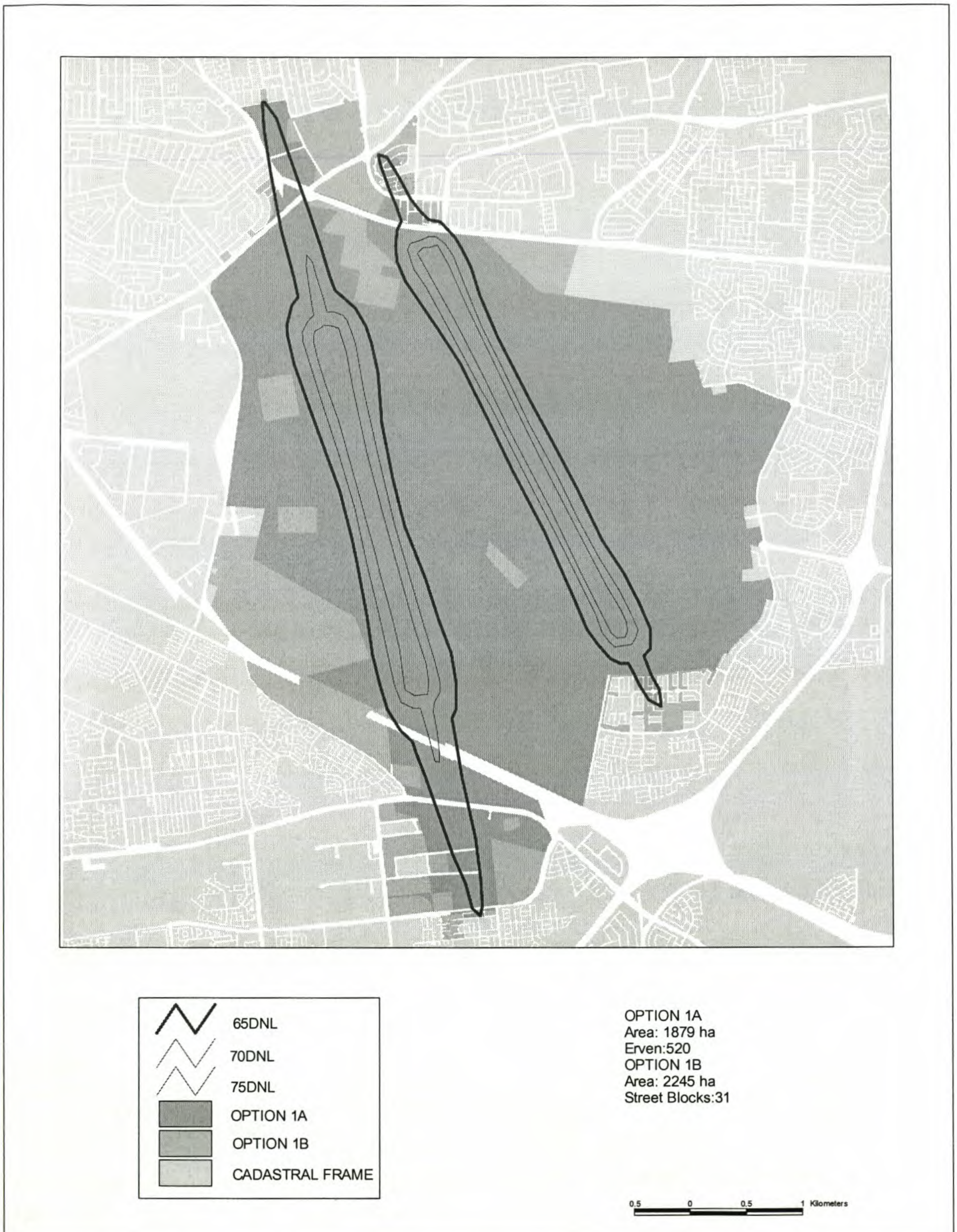

Figure 2.6. Controlled areas: Option 1A and Option 1B

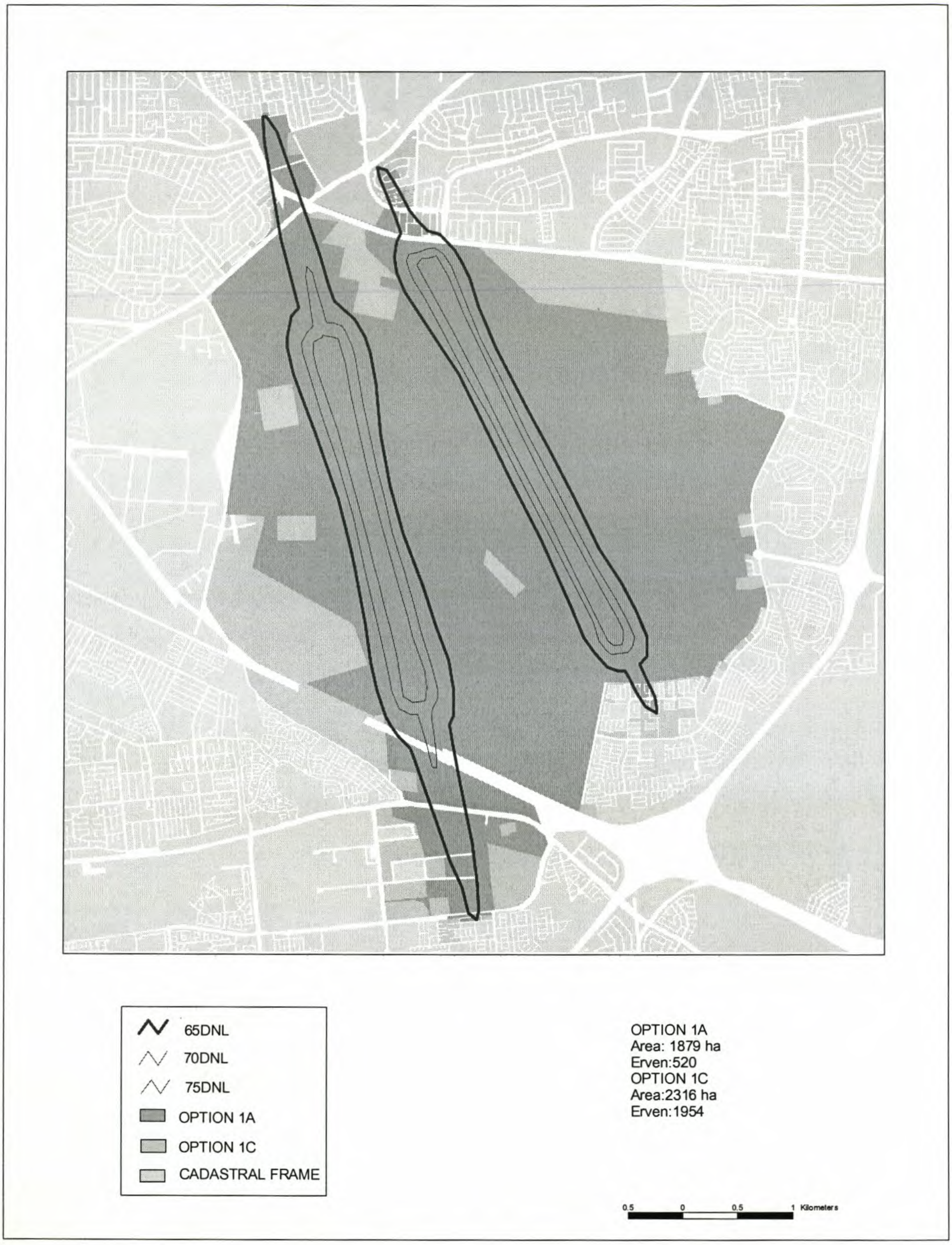

Figure 2.7. Controlled areas: Option 1A and Option 1C

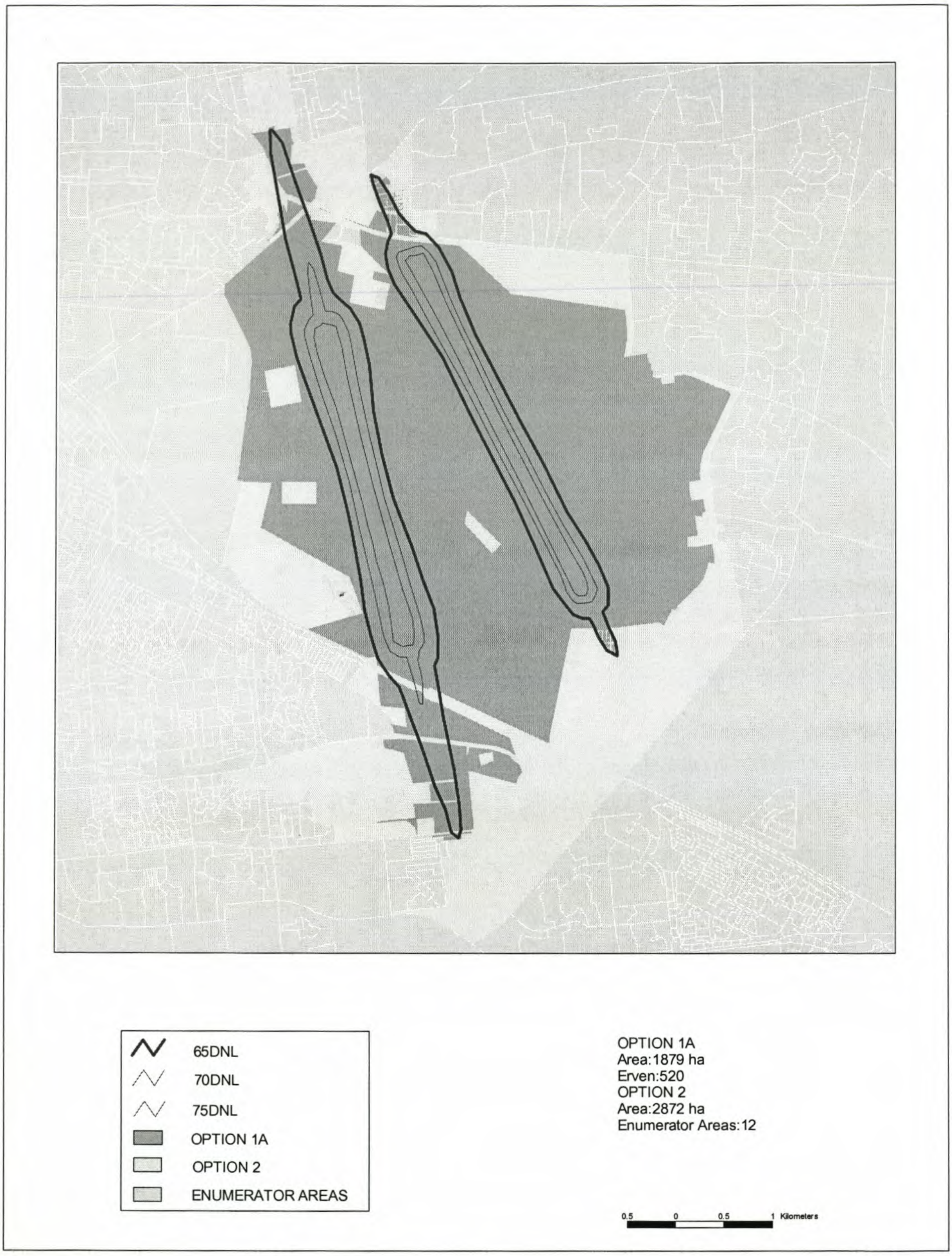

Figure 2.8. Controlled areas: Option 1A and Option 2

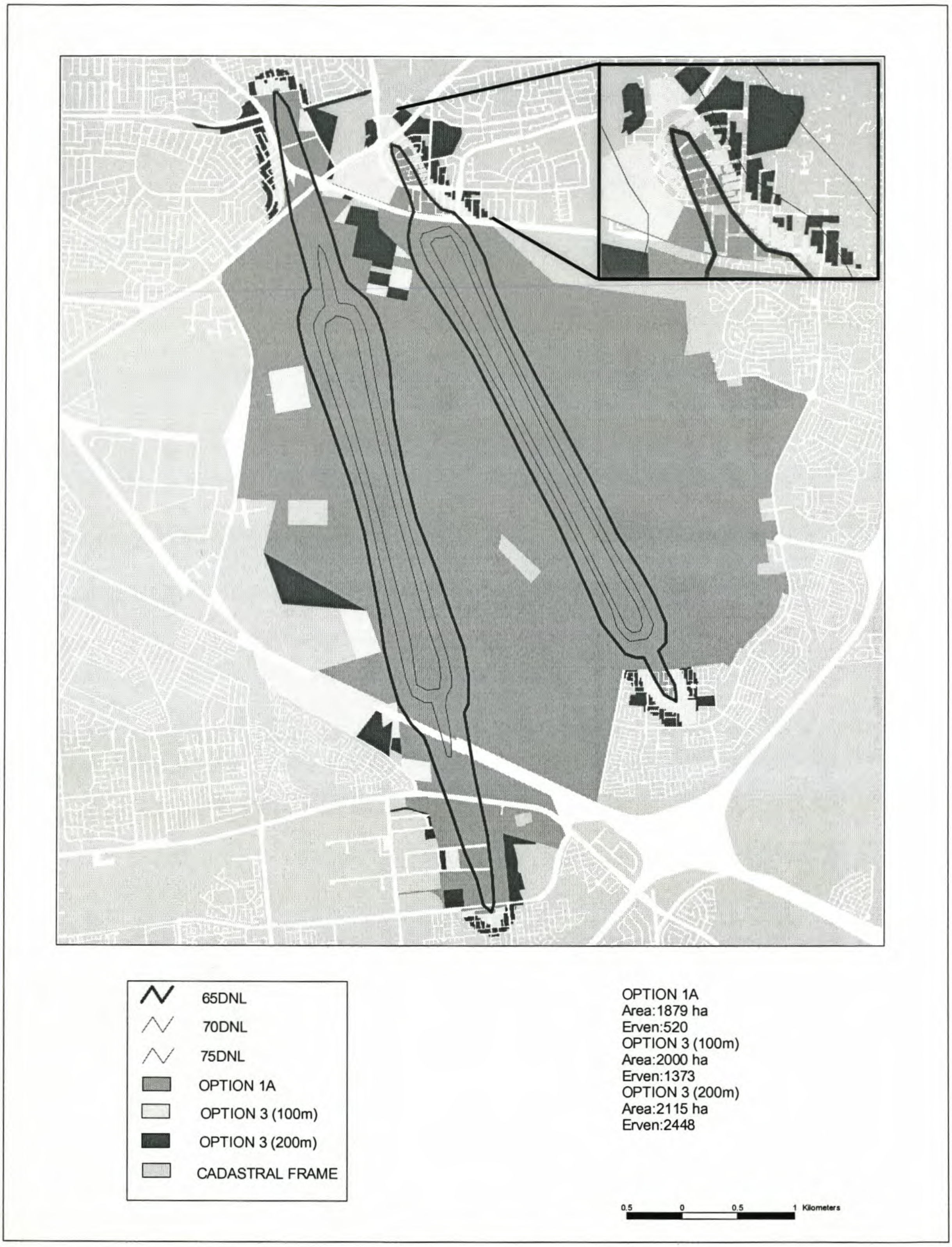

Figure 2.9. Controlled areas: Option 1A and Option 3 (buffered 100m and 200m)

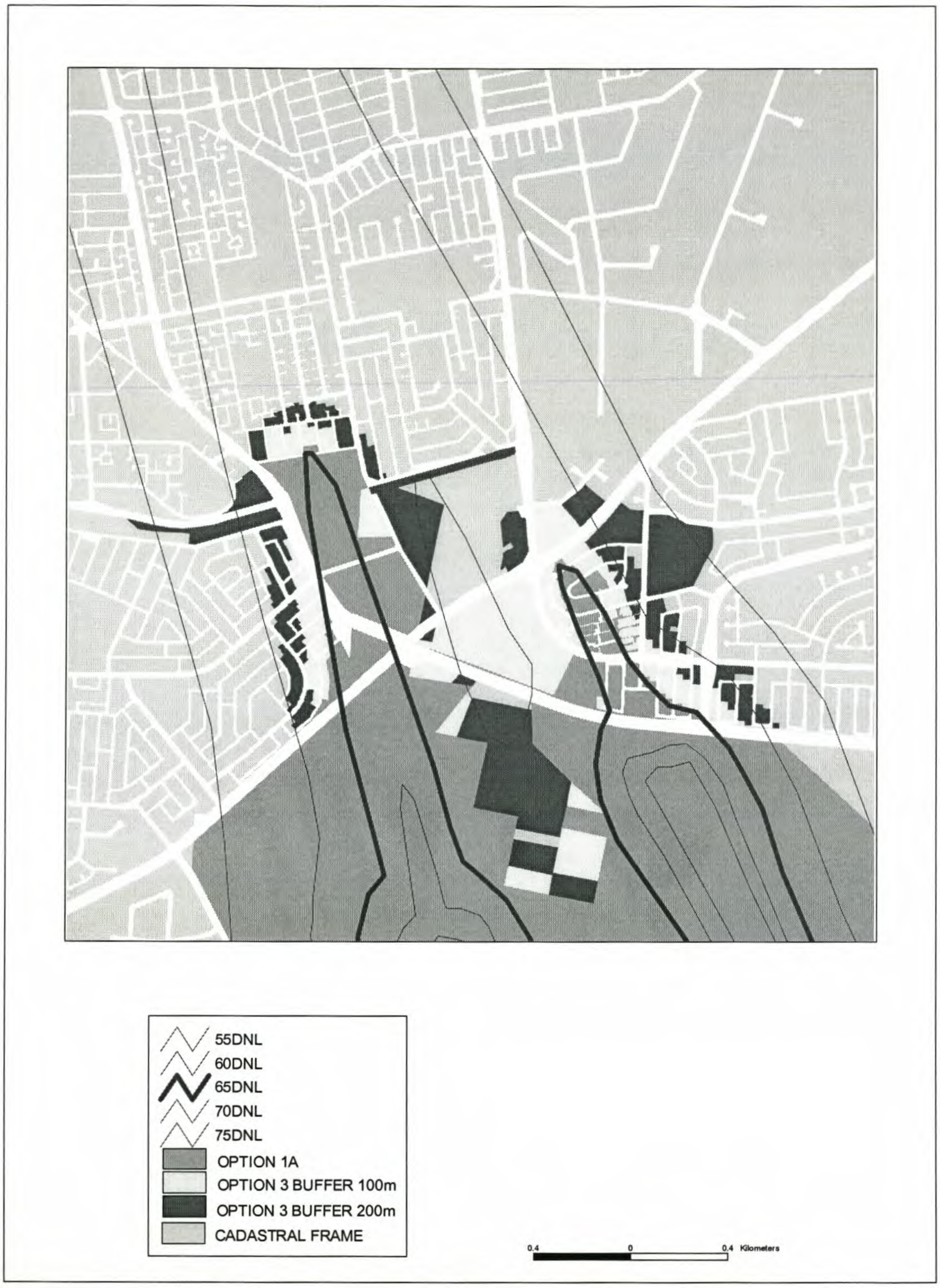

Figure 2.10 Shape of buffer zones and contour lines north of airport

2.3.4.6 Option 4: Using a different noise contour

Instead of buffering the 65DNL contour line, a different contour line can be used to create an area larger than the polygon created by the 65DNL line. Contour lines are more accurate indicators of where the noise is than buffer boundaries. Contours were interpolated linearly at intervals of 1 between 60 and 65DNL. Therefore, the rule is that all erven, enumeration areas or street blocks that intersect with the 60, 61, 62, 63 or 64DNL contour are selected. The difference in extent between the areas in property units created by these lines can be seen in Figure 2.11.

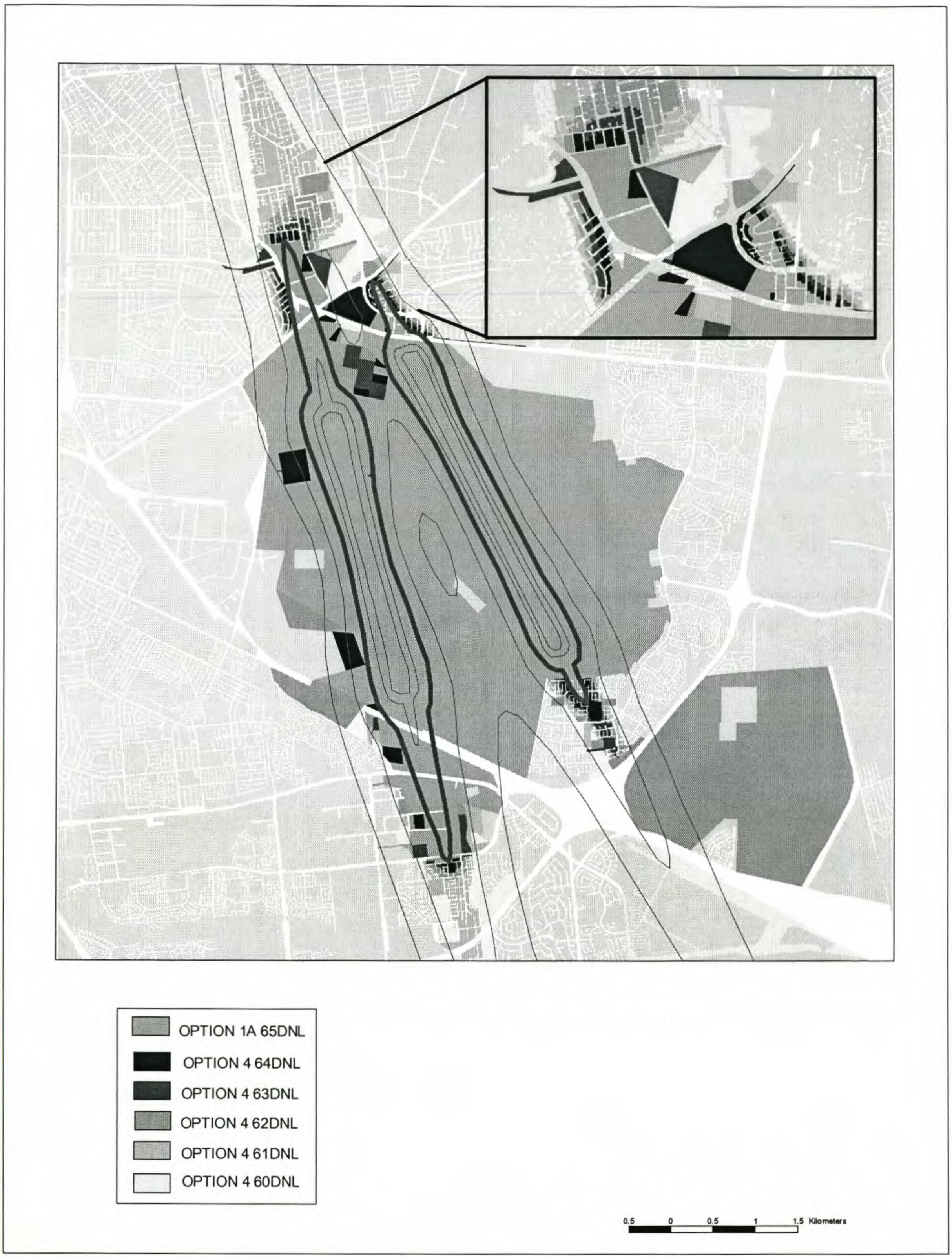

Figure 2.11. Controlled areas: Option 1A (65DNL) and Option 4 (64-60DNL)

2.4 EVALUATION OF THE DEMARCATION PROCESS

To conclude this chapter the "controlled area" options are rated, assessed and the best option is decided upon.

2.4.1 The rating criteria and procedure

The rating criteria used for evaluating the various options can be seen in Table 2.4. They were (a)the ease of the GIS procedure, (b)the resulting size of the area, (c)the practicality of the spatial unit used and (d)the international support found for the Option.. The procedure entailed giving a value of 1, 0 or –1 to each Option, according to the demarcation implications of the criteria. Positive implications received a value of 1, neutral implications received a value of 0 and if the implications were negative, a value of -1 was given. When the size of the "controlled area' was evaluated, two aspects of size were rated, the total area in hectares and the number of spatial units in the area demarcated. The median area of each Option was calculated for both the area in hectares and the number of units. Values of 1 or –1 were given to each option above or below the median, and a value of 0 given to the median value.

2.4.2 Rating application of each criterion

In this section each criterion is rated according to its implications. The ease of GIS procedure was rated according to data, time and cost implications. The size of the area was rated according to the social, economic and legal implications. The spatial unit used was rated according to the practicality of the unit to address noise issues. Lastly, the international support criterion was rated according to whether similar applications were found in international literature.

2.4.2.1 GIS procedure

The main rating criterion here is ease of operation, which have data, time and cost implications. The GIS procedures used in the demarcation process are intersection and buffering, which are relatively straightforward, quick GIS processes. The process becomes more complex and time-consuming if the data needs to be converted into different units as in option 1B and Option 1C, or the contours interpolated with new contour intervals as in Option 4. In Option 1B and Option 1C the data has to be converted into street blocks by dissolving the inner boundaries of the cadastral data, which could be a lengthy process if the study area is large. To interpolate new contour intervals, a digital elevation model (DEM) is created in Arc Info, or the INM used to create new contours at logarithmic intervals, but both processes are more complicated and increase the time taken for demarcation. The rating of the processes used in each option as shown in Table 2.4 earmark Options

Table 2.4 Rating of demarcation options for "controlled area"

OPTION	DNL CONTOUR	GIS PROCEDURE	SIZE (AREA IN HA)	RATING (SOCIAL)	RATING (ECON-OMIC)	RATING (LEGAL)	SIZE (# OF UNITS)	RATING (SOCIAL)	RATING (ECON-OMIC)	RATING (LEGAL)	PRACTICALITY OF SPATIAL UNIT	INTERNATIONAL SUPPORT	OVERALL RATING
OPTION 1A	65	Straightforward Quick 1	1879.3	-1	1	1	520	-1	1	1	Practical 1	Orlando & Minneapolis St Paul Airports 2	**6**
OPTION 1B	65	Complex Time-consuming -1	2245.3 (median)	0	0	0	31	Street blocks not comparable	Street blocks not comparable	Street blocks not comparable	Not practical -1	Orlando, Sydney & Adelaide Airports 3	**1**
OPTION 1C	65	Complex Time-consuming -1	2316.5	1	-1	-1	1954 (median)	0	0	0	Practical 1	Orlando Airport 1	**0**
OPTION 2	65	Straightforward Quick 1	2872.3	1	-1	-1	12	Ea's not comparable	Ea's not comparable	Ea's not comparable	Not practical -1	Orlando Airport 1	**0**
OPTION 3	65 (100m buffer)	Straightforward Quick 1	1999.9	-1	1	1	1373	-1	1	1	Practical 1	None found	**4**
OPTION 3	65 (200m buffer)	Straightforward Quick 1	2115.9	-1	1	1	2448	1	-1	-1	Practical 1	None found	**2**
OPTION 4	64	Complex Time-consuming -1	1951.7	-1	1	1	1061	-1	1	1	Practical 1	Orlando Airport 1	**3**
OPTION 4	63	Complex Time-consuming -1	2007.9	-1	1	1	1847	-1	1	1	Practical 1	Orlando Airport 1	**3**
OPTION 4	62	Complex Time-consuming -1	2588.6	1	-1	-1	3144	1	-1	-1	Practical 1	Orlando Airport 1	**-1**
OPTION 4	61	Complex Time-consuming -1	2732.8	1	-1	-1	5985	1	-1	-1	Practical 1	Orlando Airport 1	**-1**
OPTION 4	60	Complex Time-consuming -1	3193.3	1	-1	-1	9585	1	-1	-1	Practical 1	Orlando Airport 1	**-1**

1B, 1C and all the permutations in Option 4 as complex and hence to be avoided from a computational point of view.

2.4.2.2 Size of the "controlled area"

The size of the "controlled area' was rated according to the social, economic and legal implications thereof. When viewed from a social community perspective, the aim should be to protect as many properties as possible and therefore the larger the area and the greater the number of units included in the area, the better. If the demarcation options are considered from the economic perspective of an agency responsible for mitigation or compensation and costs of residential sound insulation are taken into account, then the larger the area, the more houses to insulate and the more expensive the procedure becomes. If the legal viewpoint is considered, then the larger the area the more people have to comply with the rules and regulations thereof and the management or policing of the "controlled area" becomes more difficult. The Options demarcating the smaller areas (Options 1A, both buffer options in Option 3 and both the 63 and 64DNL options in Option 4) were rated higher in the economic and legal categories and lower in the social category.

2.4.2.3 Spatial unit used

The resulting spatial unit of the "controlled area" was rated according to the practicality of the unit to address noise issues. It would be easier to manage the "controlled area" if it were in property units (cadastral erven), as owners can be contacted, the number of units is easier to calculate, and therefore sensitive units more easily identifiable. Enumerator areas as a unit for the "controlled area" is only useful if demographic data were required to assess noise impact on people and therefore Option 2 was rated lower than the options using cadastral erven. Option 1B which demarcates street blocks also rated lower due to the fact that street blocks are not as easy to manage as erven because of their size.

2.4.2.4 International support for options

This category was rated according to whether any of the Options were encountered in the international arena. The Orlando 'Aircraft Noise Overlay District' example discussed earlier uses a method of boundary determination similar to the intersection method. The boundaries of the noise zones were determined by whether a zone boundary line crossed or entered the plot (Federal Interagency Committee on Urban Noise 2001a). If the line crossed the plot, then the standards associated with the more stringent zone applied. If only one zone is being created, as in the demarcation of the "controlled area", then this would mean the plot is included in the zone.

Therefore all the intersection options (Option 1A, 1B, 1C, 2 and all the alternatives in Option 4) received a value of 1 for this example.

Some of the same methods of boundary determination used in the "controlled area" demarcation process were found in residential insulation programs at Minneapolis St Paul Airport, Sydney and Adelaide Airports, where boundaries for insulation eligibility have to be determined. In the residential sound insulation program at Minneapolis St Paul Airport in Minnesota, only homes wholly contained or touched by the 65DNL contour line are included. Intersect and 'touch' can be taken to mean the same in this case (Metropolitan Airports Commission 2002). Therefore Option 1A (intersection with the 65DNL contour) received a value of 1 for this example.

At Sydney Kingsford Smith Airport and Adelaide Airport in Australia, a method of boundary determination similar to the street block Option 1B was found. Where the noise exposure contour intersects a residential property within a street block, insulation eligibility is extended out from the contour line to include all other houses in that street block up to a break in continuity of residential properties – normally a street or open area. According to the Australian Department of Transport and Regional Services (2002), this is done to prevent a situation where neighbouring houses side by side might be treated differently. As a result of this example the streetblock Option 1B received a value of 2, one for each airport.

2.4.3 A noise "controlled area" for Cape Town International Airport

The four options with the highest ratings as evident in Table 2.4 are Option 1A with a rating of 6, the 100m buffering option (Option 3) with a rating of 4, and the 64DNL and 63DNL contour options (Option 4), each with a rating of 3. As mentioned in Section 2.3.4.5, the buffering options do not take the shape of the noise contours into account and many units are not included, and therefore not protected, in this option. For this reason, the researcher is convinced that the buffering option would not generate the best "controlled area". Due to the complex and time consuming GIS procedures necessary to create both alternatives in Option 4, these options were not as highly rated as Option 1A which is straightforward and quick. Option 1A is also supported by more international examples, which is another advantage.

To conclude, the evaluation shows that the best method of demarcating the "controlled area" is Option 1A where all the property units (cadastral erven) that intersect with the polygon formed by the 65 DNL noise contour are selected.

CHAPTER 3: LAND USE COMPATIBILITY FOR NOISE-CONTROLLED AREAS

The general concept of land use compatibility is reviewed in the first section of this chapter. The practical application of classifying land uses according to noise sensitivity levels at Cape Town International Airport follows, and the chapter concludes with the planning implications for incompatible land uses.

3.1 LAND USE COMPATIBILITY

Land use compatibility can be defined as the extent to which neighbouring land uses contribute jointly to, and do not mutually or singly detract from promoting the quality of life for those living within that environment. In this section land use compatibility is discussed in terms of urban environmental quality, the compatibility of airports, noise compatibility planning, and the varying noise sensitivity of different land use types.

3.1.1 Urban environmental quality through land use compatibility

The quality of the environment in an urban area influences the quality of life of its residents, workers and visitors. Goodall (2000:153) maintains that 'three factors have a particular bearing on urban environmental quality: public health and safety; provision of an efficient urban structure which facilitates human activities and movement; and, the creation of an environment which maximises people's comfort and enjoyment of living.'

Another factor closely related to urban environmental quality within an urban area is the juxtaposition of land uses. According to Goodall (2000:154), 'past and present built forms are not always good neighbours'. The more suitable and similar two adjacent land uses are, the more compatible and in harmony with each other they will be. Conversely, if two adjacent land uses are in conflict, they are viewed as being incompatible with each other and perceived as 'bad neighbours'.

Pollution is one of the factors that can create conflict between land uses and affects the kind of 'neighbour' a certain type of land use will be and, therefore, its compatibility. Examples of incompatible land uses include a sewerage plant, a power line or a railway shunting yard which adversely affect the smell, sight and hearing of residents located close to these land uses. This brings us to the question of how noise pollution from aircraft affects the compatibility of an airport and its neighbours.

3.1.2 Can airports be 'good neighbours'?

According to the FAA, a compatible land use is defined as one located adjacent to an airport that does not endanger the health, safety, or welfare of the owners, occupants, or users of the land because of exposure to levels of noise, vibrations or the risk of personal injury or property damage created by the operations of the airport, including the taking off and landing of aircraft (U.S. Department of Transportation 1999). Therefore, if an airport affects the environmental quality of urban areas close to it to such an extent that residents no longer feel safe, healthy or enjoy their every day lives, it can be viewed as a 'bad neighbour'.

Bryant (2000) maintains that, while having airport environs totally devoid of development may be ideal from a land use compatibility perspective, it seldom is a realistic objective, as existing development already makes such sterility impossible to achieve at most airports. Even in sparsely populated areas, tradeoffs must usually be made between an ideal degree of land use compatibility and the community needs for land use development. Despite the foregoing, it is important to ensure that the development that does occur is in harmony with airport operations.

Effective land use management in the crucial noise-exposed areas near airports is essential for both the continued viability of the airports and the comfort of the communities' residents. The FAA believes that communities and airports have worked at cross-purposes in the past due to a lack of communication and a lack of information on noise compatibility planning (U.S. Department of Transportation 1999).

3.1.3 Noise compatibility planning at airports

The California Department of Transportation (2002b) claims that the objective of noise compatibility planning is to minimize the number of people exposed to frequent and/or high levels of airport noise capable of disrupting noise-sensitive activities. The same department maintains that the basic strategy for achieving noise compatibility in the vicinity of an airport is to limit development of land uses that are particularly sensitive to noise. The most acceptable land uses are the ones that either involve few people (especially people engaged in noise-sensitive activities) or generate significant noise levels themselves (such as other transportation facilities or some industrial uses) leading to cumulative pollution effects.

Airport noise compatibility planning addresses both existing and future aviation noise impacts. Knowledge of future noise exposure provides a basis for long-term local planning and investment in noise mitigation for particular noise-sensitive areas, including how to compatibly develop any vacant land or to redevelop older urban areas around airports into compatible uses (U.S. Department of Transportation 1999).

Just as there are no absolute determinants of the noise level at which an individual person will be highly annoyed, there are no absolute scientific measures for establishing which land uses and noise exposures are or are not compatible with one other. The best that can be hoped for is that compatibility criteria will reflect what is appropriate for the communities involved. It is important to remember, however, that what may be considered an acceptable level of noise to a reasonable person will not satisfy 100% of the public (California Department of Transportation 2002b).

3.1.4 Varying noise sensitivity of different land use types

There is a relationship between the noise sensitivity of land use types and the resulting compatibility thereof; the less sensitive a land use is to noise, the more compatible it will be. Therefore, land use compatibility planning is important in guiding noise-sensitive land uses away from the noisier areas and encouraging non-sensitive land uses (Pereira Filho, Braaksma & Phelan 1995).

Four types of land uses are defined as incompatible (and, therefore, are the most sensitive) by the California Department of Transportation (2002a):

- residences of all types (living space);
- public and private schools (educational space);
- hospitals, clinics and convalescent homes (health facilities); and
- churches, synagogues, temples, and other places of worship (religious activity).

Owing to the fact that residential development covers the greatest proportion of urban land, noise compatibility standards usually place primary emphasis on residential areas – where people rest and live for extended periods. The sensitivity of residences can also be attributed to the fact that residential construction usually provides less sound attenuation than typical commercial construction, and windows are more likely to be open. Furthermore, people are particularly sensitive to noise at night when they are trying to sleep, and outdoor activity is a significant aspect of residential land use (California Department of Transportation 2002a).

3.2 NOISE SENSITIVITY CLASSIFICATION OF LAND USES

In the White Paper on National Policy on Airports and Airspace Management (South African Department of Transport 1998) it is specified that the authorities responsible for land use planning in the vicinity of an airport should ensure that future zoning of areas close to airports is compatible with the airport development. According to the updated National Policy on Aircraft Noise and Engine Emissions (South African Department of Transport 2002), there are land uses located within certain noise zones in the vicinity of airports that should not be there. The question is how many such cases exist at CTIA and where they are located. This chapter attempts to answer that question by examining noise sensitivity classification in South Africa and then more specifically at CTIA. By way of conclusion, the noise sensitivity classification process is evaluated.

3.2.1 Noise sensitivity classification in South Africa

Several regulations regarding noise in South Africa have resulted in a number of land use compatibility tables. The Noise Control Regulations of 1992 refer to standards set out in the SABS Code of Practice (0117-1974) that recommend limits for land use developments. These regulations place a general prohibition on the erection of educational, residential, hospital, church or office buildings within a "controlled area" unless special acoustic screening measures are applied to ensure that acceptable interior noise levels can be maintained. The limits can be seen in Table 3.1.

Table 3.1 Noise limits for land use development

LAND USE DEVELOPMENT	NOISE INDEX (NI)
Schools, universities, churches, hospitals	Max 60
Residential areas	Max 65
Residential areas with acoustically insulated buildings	Max 75 (20 dBA difference between inside and outside)
Industrial areas	Max 85
Forbidden areas: no residential/commercial/industrial uses	More than 85

Source: South African Department of Transport, 1999:54

In order to facilitate land use planning and the interpretation of different noise contours, it was proposed that additional information be included in the above table to create a new land use compatibility table to be used in the Updated National Policy on Aircraft Noise and Engine Emissions 1999. But, according to Swanepoel (2002, Pers com), a simplified land use compatibility table will be used in the National Policy which will only be used by acoustic engineers in measuring noise disturbance and not by town planners in determining suitable land uses.

The SABS has decided that the more detailed land use compatibility table to be used by town planners, will be drafted by the Association of Municipal Town and Regional Planners. As Chairperson of this association, Mr Swanepoel will initiate the process to finalise such a table in conjunction with the Metropolitan Councils and municipalities of Cape Town, Durban, Johannesburg and Pretoria. There is however, no fixed timeframe for this as yet. The following draft Table 3.2, can thus only be considered as a first attempt in the process, with no legal status.

Table 3.2 Draft land use compatibility table for town planners

	Noise Zones (DNL)								
Land uses	**<45**	**45-50**	**50-55**	**55-60**	**60-65**	**65-70**	**70-75**	**75-80**	**80>**
High density residential (more than 100 units per hectare)	✓	✓	✓	?	✕	✕	✕	✕	✕
Medium density residential (25 to 100 units per hectare)	✓	✓	✓	✓	✕	✕	✕	✕	✕
Low density residential (less than 25 units per hectare)	✓	✓	✓	✓	✓	✕	✕	✕	✕
Temporary Residential: hotels, motels, guest houses, etc	✓	✓	✓	✓	✓	?	✕	✕	✕
Educational (university, college, school, crèche, day care center)	✓	✓	✓	✓	?	✕	✕	✕	✕
Hospital, Clinic	✓	✓	✓	✓	?	✕	✕	✕	✕
Other medical (doctor, dentist, vet, etc) consulting rooms	✓	✓	✓	✓	✓	✕	✕	✕	✕
Church (and other places of worship)	✓	✓	✓	✓	?	✕	✕	✕	✕
Community hall & library	✓	✓	✓	✓	✓	?	✕	✕	✕
Office (including banks)	✓	✓	✓	✓	✓	?	?	✕	✕
Whole sale	✓	✓	✓	✓	✓	✓	✓	✕	✕
Retail (low intensity)	✓	✓	✓	✓	✓	✓	?	✕	✕
Retail (high intensity)	✓	✓	✓	✓	✓	?	✕	✕	✕
Food and drink retail	✓	✓	✓	✓	✓	✓	?	✕	✕
Public garage	✓	✓	✓	✓	✓	✓	✓	✕	✕
Motor trade and related uses	✓	✓	✓	✓	✓	✓	✓	✕	✕
Panel beat & Spray paint	✓	✓	✓	✓	✓	✓	✓	✕	✕
Scrap yard	✓	✓	✓	✓	✓	✓	✓	✕	✕
Exhibition centres	✓	✓	✓	✓	✓	✓	?	✕	✕
Conference facilities	✓	✓	✓	✓	✓	?	?	✕	✕
Manufacturing	✓	✓	✓	✓	✓	✓	✓	✕	✕
Assembly plant	✓	✓	✓	✓	✓	✓	✓	✕	✕
Repairing	✓	✓	✓	✓	✓	✓	✓	✕	✕
Packaging	✓	✓	✓	✓	✓	✓	✓	✕	✕
Transport company	✓	✓	✓	✓	✓	✓	✓	✕	✕
Distribution Centre	✓	✓	✓	✓	✓	✓	✓	✕	✕
Warehousing	✓	✓	✓	✓	✓	✓	✓	✕	✕
Bus, municipal and other Depots	✓	✓	✓	✓	✓	✓	✓	✕	✕
Builders yard	✓	✓	✓	✓	✓	✓	✓	✕	✕
Parking garage	✓	✓	✓	✓	✓	✓	✓	✓	✕
Sport and Recreation (low intensity); e.g. Golf Course	✓	✓	✓	✓	✓	✓	✓	✓	✕
Sport and Recreation (high intensity); e.g. Soccer Stadium	✓	✓	✓	✓	✓	✕	✕	✕	✕
Entertainment	✓	✓	✓	✓	✓	?	✕	✕	✕
Restaurant, fast food, road house, pub, tea garden, etc	✓	✓	✓	✓	✓	?	✕	✕	✕
Picnic facility	✓	✓	✓	✓	✓	✓	✓	✕	✕
Open Space (Vacant land)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Agricultural (crop farming)	✓	✓	✓	✓	✓	✓	✓	✓	✕
Agricultural (cattle farming)	✓	✓	✓	✓	✓	✓	✓	✕	✕
Cemetery	✓	✓	✓	✓	✓	✓	✓	✕	✕
Direct airport uses (passengers)	✓	✓	✓	✓	✓	?	?	✕	✕
Direct airport uses (cargo, maintenance, etc)	✓	✓	✓	✓	✓	✓	✓	✕	✕

Key

✓: land use to be allowed in the specific DNL Zone (compatible)

?: land use to be allowed, but with acoustic screening to 40 DNL (compatible with restrictions)

✕: land use not to be allowed in the specific DNL Zone (incompatible)

Source: Swanepoel (2002, Pers com.)

The above draft table was consolidated from the following noise regulations: Western Province Noise Control Regulations 1998; Gauteng Province Noise Control Regulations 1999; Land use planning in the Johannesburg International Airport (JIA) Noise Zone 1998; SABS 0103 Edition 5 (Draft) 2001; and, the National Policy on Aircraft Noise 1999 (Swanepoel 2002, Pers com).

3.2.2 Noise sensitivity classification at Cape Town International Airport

The noise sensitivity classification process involves building a GIS database of land use types in the noise sensitive area around Cape Town International Airport, classifying these land use types according to noise sensitivity levels and identifying the incompatible land uses. With this information, priority areas for land use compatibility projects can be determined.

3.2.2.1 Creation of the land use database

The first task was to build a GIS database of land use types in the noise "controlled area" around CTIA using land use and zoning data received from the City of Cape Town. This involved reclassifying the land use and zoning data received into the corresponding land use types used in the land use compatibility table proposed by the town planners.

The land use data received did not cover the whole area spatially, which made it necessary to use zoning data for the records which had no land use type. This process had a number of disadvantages which will be discussed in the section on the evaluation of the classification. A number of land uses were identified in the data that were not included in the draft table. The suggestions for classification can be seen in Table 3.3.

The wetlands, water supply, sewage/storm water facilities and solid waste disposal categories were classified in the same way as vacant land, but should for safety reasons not be allowed in the flight path because of the risk of bird strikes. Owing to the fact that the mining and quarrying, recycling, gas and electricity supply and galvanising and sandblasting categories have the same noisy environment as manufacturing, they were classified as such. The road, rail and marine transport categories were viewed the same as vacant land, as they are land uses not influenced by noise.

A number of land uses found in the data were not regarded as land use types by the town planners and, therefore, not given noise classifications. These land use types have institutional functions and are, therefore, not regarded as separate land use types and are listed in Appendix A Table A.1.

3.2.2.2 Classification of land uses and determination of incompatible land uses

The second task was to classify the land use and zoning data by assigning maximum noise levels in DNL allowed for each land use type, according to the draft land use compatibility table compiled by the town planners. The land use classification table, Table A2, and the zoning classification table, Table A3, can be found in Appendix A.

Table 3.3 Land use types identified in the data that were not given classifications in the draft land use compatibility table and their suggested classifications

	Noise Zones (DNL)									
Land use types	**<45**	**45-50**	**50-55**	**55-60**	**60-65**	**65-70**	**70-75**	**75-80**	**80>**	**Suggestions for classification**
Nature Reserves	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as agriculture (cattle farming).
Water Areas/Wetlands	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as vacant land, except if it's a nature reserve, then the same as agriculture (cattle farming).
Wilderness Areas	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as agriculture (cattle farming).
Forestry	✓	✓	✓	✓	✓	✓	✓	✓	×	Same principle as agriculture (crop farming).
Fisheries	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as agriculture (cattle farming).
Mining & Quarrying	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as manufacturing.
Recycling	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as manufacturing.
Gas & Electricity supply	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as manufacturing.
Water supply	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as vacant land.
Galvanising, sandblasting	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as manufacturing.
Roads	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as vacant land.
Rail Transport	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as vacant land.
Marine Transport	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as vacant land.
Communications	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as offices.
Transport & Communication (Other)	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as transport company.
Sewage/Storm water Facilities	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as vacant land.
Solid Waste Disposal	✓	✓	✓	✓	✓	✓	✓	✓	✓	Same principle as vacant land.
Public Open Spaces	✓	✓	✓	✓	✓	✓	✓	×	×	Same principle as picnic facilities.
Personal Services	✓	✓	✓	✓	✓	?	?	×	×	Same principle as offices.
Police Station	✓	✓	✓	✓	✓	?	?	×	×	Same principle as offices.
Fire Station	✓	✓	✓	✓	✓	?	?	×	×	Same principle as offices.
Health (Ambulance Service)	✓	✓	✓	✓	✓	?	?	×	×	Same principle as offices.
Judicial facilities	✓	✓	✓	✓	✓	?	?	×	×	Same principle as offices.

Key

✓: land use to be allowed in the specific DNL Zone (compatible)

?: land use to be allowed, but with acoustic screening to 40 DNL (compatible with restrictions)

×: land use not to be allowed in the specific DNL Zone (incompatible)

The classification resulted in two options, a conservative and a liberal option. The conservative option presumes that no acoustical screening has taken place, while the liberal option allows the land use to be in a certain noise zone, but only with acoustical screening. Once the maximum noise levels for each land use type were assigned, the land use cases for each noise level were intersected with the noise contours to determine the incompatible cases. The number of incompatible cases of land use types identified when using these two options is indicated in Table 3.4.

Table 3.4 Occurrence of erven with incompatible land use types

CONSERVATIVE OPTION, WITHOUT ACOUSTICAL SCREENING

Noise levels in DNL	55-60 zone	60-65 zone	65-70 zone	70-75 zone	>75 zone
80>	0	0	0	0	0
Max 80	0	0	0	0	0
Max 75	0	0	0	0	2
Max 70	0	0	0	0	0
Max 65	0	0	102	0	0
Max 60	0	553	96	0	0
Max 55	2617	1776	178	0	0
Total	**2617**	**2329**	**376**	**0**	**2**

LIBERAL OPTION, WITH ACOUSTICAL SCREENING

Noise levels in DNL	55-60 zone	60-65 zone	65-70 zone	70-75 zone	>75 zone
80>	0	0	0	0	0
Max 80	0	0	0	0	0
Max 75	0	0	0	0	2
Max 70	0	0	0	0	0
Max 65	0	0	99	0	0
Max 60	0	2230	272	0	0
Max 55	No cases in data				
Total	**0**	**2230**	**371**	**0**	**2**

The conservative classification option selects the largest number of incompatible cases. The reason for this is the large amount of high density residential land use that is only allowed in the maximum 55DNL noise zone but located in the 55-60DNL & the 60-65DNL zones.

3.2.2.3 Identification of priority areas

The priority areas in this study are the areas that contain sensitive land use types located in incompatible noise zones. The FAA selected 65DNL as the dividing point between normally compatible and normally incompatible residential and other noise sensitive land uses (California Department of Transportation 2002a). As mentioned in Section 3.1.4, there is a positive relationship between land use compatibility and noise sensitivity. Therefore, sensitive land uses were identified as those that can only be subjected to noise levels of 65DNL or less, namely categories with maximum noise levels of 55, 60 and 65DNL. The priority areas were rated according to the DNL difference between the allowed zone and the zone they were located in. The area with the largest difference was given a rating of 1 and the areas with the smallest difference a rating of 3. The two areas with the highest priority rating of 1 are both high density residential located in Delft and Philippi. The priority areas identified and the degree of priority, using the conservative option are indicated in Table 3.5 and displayed in Figure 3.1.

Table 3.5 Priority areas and incompatible land use types

Maximum noise level (in DNL)	Noise zone	Priority Rating	Number of incompatible cases	Land use types
Max 55	65-70	1	178	High density residential
			178	TOTAL
Max 55	60-65	2	1776	High density residential
			1776	TOTAL
Max 60	65-70	2	94	Medium density residential
			2	Educational
			96	TOTAL
Max 55	55-60	3	2617	High density residential
			2617	TOTAL
Max 60	60-65	3	453	Medium density residential
			80	Educational
			13	Religious activities
			7	Hospital, clinic
			553	TOTAL
Max 65	65-70	3	97	Low density residential
			2	Community Hall
			2	Offices
			1	Retail (high intensity)
			102	TOTAL

The land use types that constitute the priority areas include residential, educational, religious activities, hospitals, community halls, offices and high intensity retail. As can be seen in Figure 3.2, high density residential areas cover the largest area and also have the highest priority rating of 1. Medium density residential and educational areas also cover a significant area and have a priority rating of 2 in some areas and 3 in others.

3.2.3 Evaluation of the noise sensitivity classification method

The researcher regards the method of substituting zoning data for land use data as not ideal, as the zoning categories are often too broad and the data too generalised. Examples include the zoning category Transport 1, which includes railway lines, bus depots, taxi ranks and truck stops and the zoning category Rural, which includes both cattle and crop farming. These are individual land use categories in the land use compatibility table, but are grouped together in the zoning data. Furthermore, the zoning data for the area south of the N2 was more generalised than the land use data. In addition, if a piece of land is zoned as something, it is not necessarily always used as such.

When intensities of land use types were allocated, for example in the retail and sport categories, and it was not clear from the data which intensity the land use type was, the higher intensity and, therefore, the more people involved, was always chosen. This was done keeping the objective of noise compatibility planning, which is to minimize the number of people exposed to high levels of airport noise capable of disrupting noise-sensitive activities, in mind.

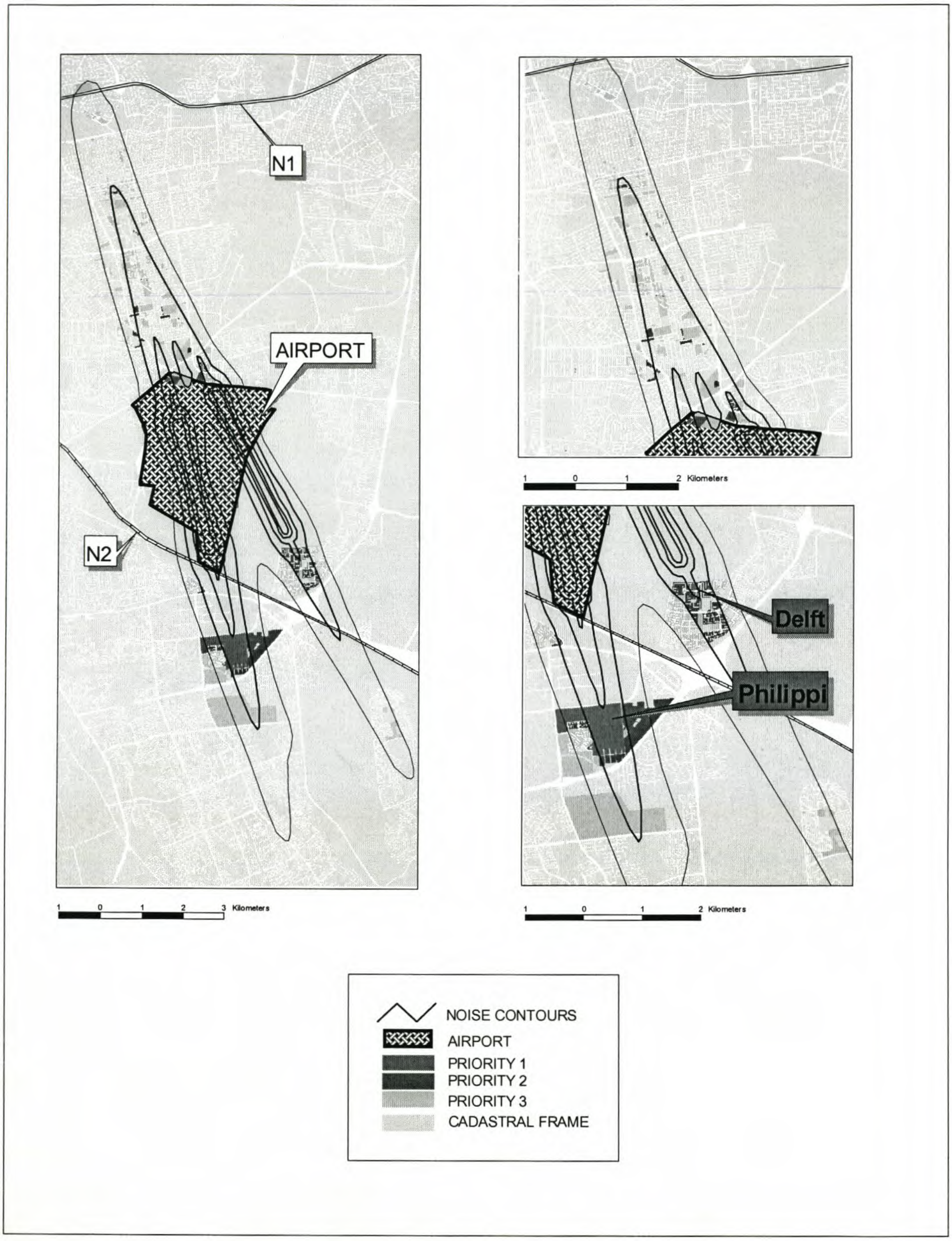

Figure 3.1 Priority (noise sensitive) areas at Cape Town International Airport

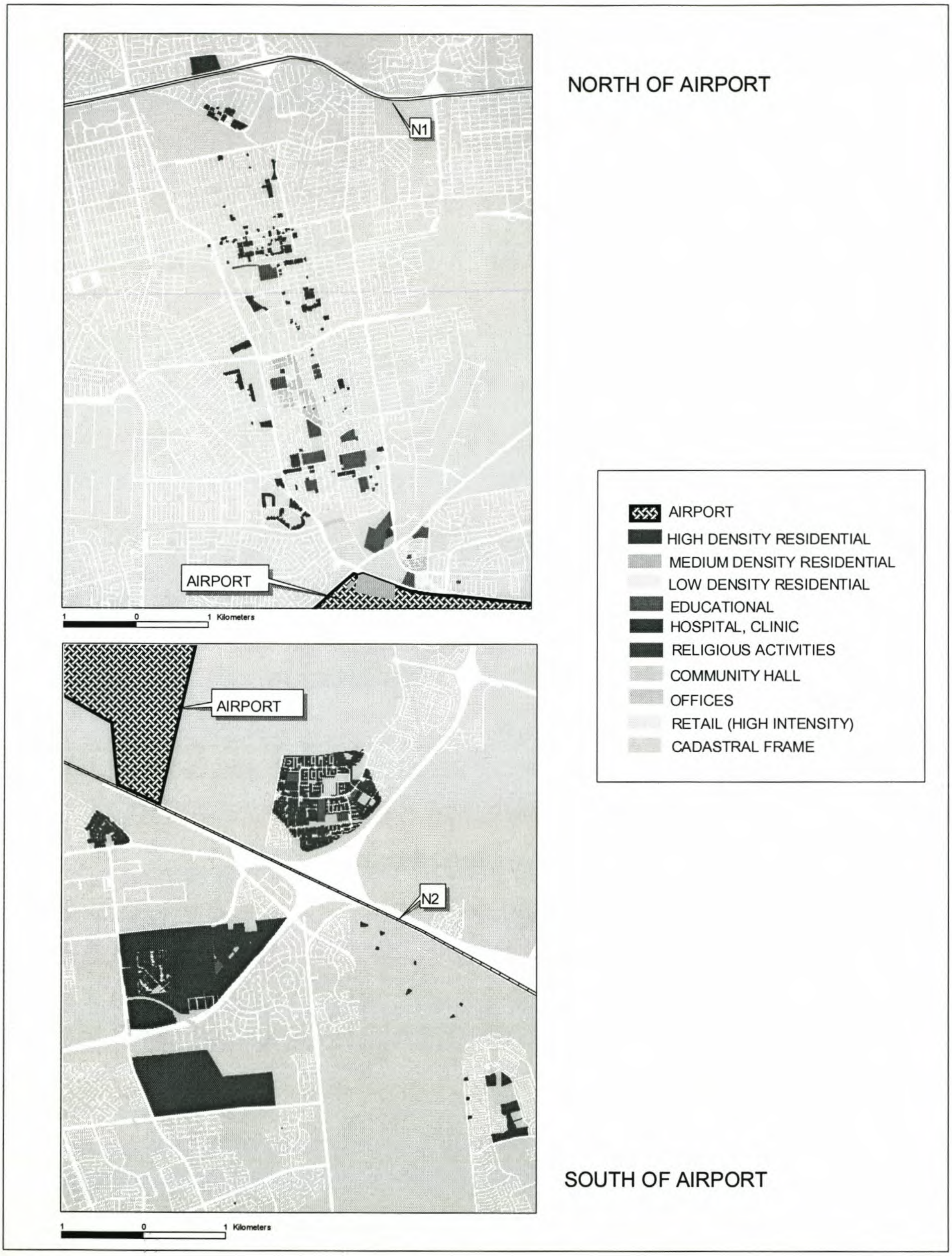

Figure 3.2 Land use types in the priority areas

3.3 PLANNING IMPLICATIONS FOR INCOMPATIBLE LAND USES

Once all incompatible land uses are identified, the next task (of the local authority) is to draft an action plan to address these land uses. According to the Airports Company South Africa (2001), the action plan should be drafted in consultation with the affected property owners and must include an implementation program and a budget. In this section the various remedial actions that can be taken to address incompatible land uses around airports are discussed and conclusions are reached with recommendations for an action plan for Cape Town International Airport.

3.3.1 Remedial actions

According to the South African Department of Transport (1999), a wide variety of measures to deal with incompatible development around airports have been implemented in other countries, including:

- environmental impact assessments
- land acquisition and relocation
- noise insulation programs
- subdivision regulations and tax-incentives
- transaction assistance and transfer of development rights
- comprehensive and integrated planning

The Draft National Policy on Aircraft Noise and Engine Emissions (South African Department of Transport 1999) recommended four preferred remedial actions for South Africa. These include:

- **Insulation:** Installation of sound insulation in structures is suitable as a land use compatibility measure for highly noise-impacted locations. The California Department of Transportation (2002a) maintains that sound insulation should be regarded as a measure of last resort and should not be a substitute for good prior land use compatibility planning.
- **Relocation:** Noise-sensitive land uses such as schools and hospitals can be relocated to areas with more acceptable noise levels and the old buildings recycled for a more compatible use.
- **Exception:** In some instances, local authorities may make an exception and allow a particular undesirable land use due to specific circumstances. This only applies to existing incompatible land uses and no new incompatible land uses may be allowed (South African Department of Transport 1999).
- **Land acquisition:** The airport may purchase land designated for undesirable uses within certain noise contours for its own (airport-related) use. The airport owner may choose to

demolish all existing buildings on these properties to prevent future problems (South African Department of Transport 1999).

3.3.2 Recommendations towards an action plan for Cape Town International Airport

Noise solutions are airport-specific. No two airports are alike in their noise and land use environments. The best solutions for one airport may not be effective or desirable in another location (U.S. Department of Transportation 2000a). Therefore, it is important for CTIA to draft an action plan that suits the airport and that the appropriate remedial actions contained in the National Policy on Aircaft Noise be included.

The Department of Transport requested that the **insulation of houses** be omitted from the National Policy on Aircraft Noise and Engine Emissions due to the fact that there would never be sufficient funds to either resettle the informal communities within the "controlled area" in Cape Town or effectively insulate the homes of these residents (Krynauw, 2002). The researcher is of the opinion that, even though insulation and relocation as remedial actions are not particularly suited to the areas neighbouring Cape Town International Airport, they should still be included in the National Policy.

Relocation as a remedial action is very costly and not as practical for communities in existing incompatible, formal residential areas. However, for communities living in informal shacks and shanty towns, relocation to more suitable areas is advisable. Informal housing areas as a land use type are more sensitive to noise due to the structure of the housing. Consequently, they should be given a greater priority than formal residential areas.

According to Krynauw (2002, Pers com), although insulation may not be as effective for land use types in South Africa as it is in Europe or the USA because of our mild climate, outdoor lifestyle and the structure of buildings in low-cost housing developments, a degree of insulation can still be achieved by replacing doors and windows with thicker materials and fitting ceilings in houses.

The above measures could form part of an **urban renewal project**, with the focus on improving the physical living conditions of communities around CTIA. An urban renewal project has been undertaken in Uitsig to identify and assess realistic options to upgrade and rejuvenate the urban fabric, social facilities and civil infrastructure and to address the dominant socio-economic problems experienced by the community. The U.S. Department of Transportation (2000a) maintain that community involvement is a critical part of airport noise compatibility planning. Community representatives can provide input on the noise mitigation measures that are the most desirable to airport neighbours around Cape Town International Airport and inform the public of the technical and reasonable limits to noise reduction.

Another factor to take into account when drafting an action plan is both the existing noise and **future growth** of the airport, so that these lands can be reserved for uses that are compatible with the airport, both now and in the future. Noise reductions won through the very **costly phase out of noisy Chapter 2 airplanes** may be wasted if authorities permit new noise-sensitive uses to follow the retreating noise contours too quickly and too closely. It is important to remember that effective airport noise compatibility planning is a continuous process rather than a one-time accomplishment (U.S. Department of Transportation 2000a).

The feasibility or cost effectiveness of actions, whether **remedial or preventative**, must also be taken into account. For example, it is usually more feasible to avoid the creation of new incompatible land uses than it is to reduce existing noise impacts through land use changes. Moreover, while the benefits or effectiveness may be the same in each case, the cost of eliminating or mitigating existing land use incompatibilities is usually far greater than avoiding it in the first place (California Department of Transportation 2002a).

To conclude, it is important to keep in mind the following vision for integrating airports into the environment, as expressed in the White Paper on National Policy Airports and Airspace Management: "Accessible airports integrated into and operating in their natural and built environments, while performing their function in the economy and the transport system, and serving and benefiting their affected communities, with minimized negative impacts on both the built and natural environments" (South African Department of Transport 1999).

CHAPTER 4: POPULATION EXPOSED TO AIRCRAFT NOISE

In this chapter the effects of aircraft noise on communities is discussed, followed by a section on the vulnerability of communities to aircraft noise. The focus then shifts to the vulnerable groups identified around Cape Town International Airport.

4.1 EFFECTS OF AIRCRAFT NOISE ON COMMUNITIES

According to Basrur (2000:5), a working group on environmental noise in Canada acknowledged that "Noise is more than just a nuisance since it constitutes a real and present danger to people's health. Day and night, at work and at play, noise can produce serious physical and psychological stress. No one is immune to this stress. People appear to adjust to noise by ignoring it but the ear, in fact, never closes."

In this section the types of effects of aircraft noise on communities are examined. After that, the relationship between noise exposure and annoyance is explored, and the section concludes with a discussion of noise complaints received generally.

4.1.1 Types of effects

Noise, especially aircraft noise, affects people and their activities in varied and complex ways. Three principal types of effects on people can be identified: physiological, behavioural and subjective.

4.1.1.1 Physiological effects

Physiological effects can be either temporary or permanent. Temporary effects include startle reactions and the effects of sustained sleep interference. Hearing loss is the most obvious permanent effect of noise although in some cases the damage is only temporary. According to the California Department of Transportation (2002a), the non-auditory health effects of aircraft noise have not yet been quantified, although research implicates noise as one of several factors producing stress-related health effects such as heart disease, high blood pressure and stroke, ulcers and other digestive disorders.

4.1.1.2 Behavioural effects

Behavioural effects are usually measured in terms of interference with human activities, namely sleep, speech and task interference. The extent to which environmental noise disturbs human sleep patterns varies greatly from individual to individual as well as from one time to another for any particular individual. Also, according to Kryter (1994), most people adapt over time to increased levels of noise during sleep. Whether the noise source emanates from outdoors, as is the case with aircraft noise, type of construction of the house, and whether the windows are open or closed are important factors in determining the loudness of the noise as heard indoors.

Speech interference is an often-cited example of the effect of aircraft noise. As can be seen in Table 4.1, a sound level of 45dBA will permit relaxed conversation with 100% intelligibility throughout a typical residential living room. When the noise level approaches 80dBA, intelligibility drops to near zero, even when a loud voice is used (California Department of Transportation 2002a).

Table 4.1 Speech interference and sound levels

Sound level (dBA)	Intelligibility	Conversation
45	100%	Relaxed conversation
64	95%	Satisfactory conversation
80	Near 0	No conversation

Source: California Department of Transportation 2002a: 7-9

Closely related to speech interference is task interference, which includes the effects of noise on learning and, more broadly, on cognitive tasks. Studies have shown a strong relationship between noise and children's reading ability and attention spans. Adults are also adversely affected by noise, and some studies indicate that, in a noisy environment, adults have increased difficulty accomplishing complex tasks (California Department of Transportation 2002a).

4.1.1.3 Subjective effects

By their very nature, subjective effects are unique to each individual and, therefore, difficult to quantify. Subjective effects of noise are commonly described in terms of annoyance, which is defined by Basrur (2000:8) as "...the expression of negative feelings resulting from interference with activities, as well as disruption of one's peace of mind and the enjoyment of one's environment." Because of the great variability in the ways people perceive and react to the unpleasant aspects of noise, prediction of how any one individual will react is nearly impossible. Most research consequently focuses on identifying predictable results among a group or community of people (California Department of Transportation 2002a). The relationship between annoyance and noise exposure will be further examined in the next section.

4.1.2 Noise exposure and annoyance

The most widely accepted evaluation of the relationship between transportation noise exposure (not exclusively aviation noise) and the extent of annoyance was one originally developed by Schultz in 1978 and later updated by the U.S. Air Force in 1992 (California Department of Transportation

2002a). This relationship, known as the 'Schultz curve' indicates the percentage of people found to be highly annoyed at various levels of noise exposure measured in terms of the DNL metric.

As can be seen in Table 4.2, the 'Schultz curve' indicates that 12% of the population is significantly annoyed at 65DNL, which is the commonly referenced dividing point between lower and higher rates of people describing themselves as being highly annoyed. The community reaction and community attitudes at different sound and annoyance levels are also indicated in Table 4.2.

Table 4.2 Effects of noise on people

DNL Sound Level	Hearing Loss	Annoyance experienced	Average Community Reaction	General Community Attitude Toward Area
>75	May begin to occur	37%	Very severe	Noise is likely to be the most important of all adverse aspects of the community environment.
70	Will not likely occur	22%	Severe	Noise is one of the most important of all adverse aspects of the community environment.
65	Will not occur	12%	Significant	Noise is one of the most important of all adverse aspects of the community environment.
60	Will not occur	7%	Moderate	Noise may be considered an adverse aspect of the community environment.
<55	Will not occur	3%	Slight	Noise is considered no more important than various other environmental factors.

Source: California Department of Transportation 2002a: 7-15

Three-dimensional representations of affected communities in the vicinity of an airport can be illustrated cartographically as possible 'annoyance mountains'. Through overlay of the calculated noise values on the ground with the population size of the communities, it is possible to calculate who will be affected by disturbance from aircraft noise and where they are located (Schaller J 1990).

4.1.3 Noise complaints

One manner in which annoyance at noise is sometimes exhibited is through complaints. Many airports maintain logs of noise complaints received. In addition to providing an avenue for people to express their concerns, noise complaints can help in identifying the nature and location of particular airport noise problems. The California Department of Transportation (2002a) maintains that complaints cannot necessarily always be equated to annoyance rates within a community. Annoyance can exist without resulting in complaints, and complaints may occur even without a high rate of annoyance. Moreover, there is not necessarily a correlation between complaints and noise exposure. At many airports, residential areas subjected to the highest noise levels produce relatively few complaints, perhaps because of the predictability of the events. It is more common for the majority of complaints to originate from locations outside the defined noise contours. Most complaints tend to be associated with:

- exceptionally loud, large, or low-flying aircraft which are not normal for the airport;
- changes in flight patterns which cause increased noise impacts; or
- a small number of people who frequently complain about airport activities.

4.2 VULNERABILITY OF COMMUNITIES TO AIRCRAFT NOISE

Noise levels in some communities near major airports have become so intolerable that many residents cannot continue to live in those communities. According to Anthrop (1973), this situation illustrates what is perhaps the basic conflict over aircraft noise, namely that one group of people enjoys the economic benefits of the air transportation industry while a different group, which derives no benefits, is subjected to the noise. The groups that are subjected to aircraft noise are often more vulnerable than those benefiting from airports, which makes the situation worse for them. There is a profound conflict between the interests of the noise-weary residents whose quality of the environment deteriorates as the noise exposure increases, and those with an economic interest in airports.

Certain people or households are more at risk from environmental hazards such as aircraft noise due to the fact that they are less able to avoid them, more affected by them, or less able to cope with the effects they cause (Danish Agency for Development Assistance 2000). Such individuals or households are generally termed vulnerable or susceptible. The vulnerability of communities is influenced by many factors, namely demographic, physical and socio-economic, which are discussed in the rest of this section.

4.2.1 Demographic characteristics

Age and gender are two demographic factors influencing vulnerability. With regards to age, it is the young and the elderly that are the most vulnerable. Children are a high-risk group vulnerable to the effects of noise due to the fact that they are in the process of learning. Research on the effects of aircraft noise on children's learning suggests that aircraft noise can interfere with learning in the following areas: reading, motivation, language and speech acquisition and memory (Stansfeld et al. 2000). According to the Federal Interagency Committee on Aviation Noise (2000), the strongest findings are in the area of reading, where more than 20 studies have shown that children in noise impact zones are negatively affected by aircraft. Noise also interrupts communication in the classroom, which has led to the nickname "jet-pause" teaching (Holland 2001). Amongst children, there are specific vulnerable groups like children with lower aptitudes, children with hearing problems or children learning in a non-native language (Federal Interagency Committee on Aviation Noise 2000).

The elderly are also vulnerable due to the fact that they are more sensitive to environmental stressors like aircraft noise and have reduced adaptability or reserve capacity to deal with the effects of noise. The elderly are more likely to have hearing impediments and are more affected by speech and sleep interference. Studies have also shown a relatively strong effect of noise on the ability to memorize in the elderly (Miedema 2001).

Another vulnerable group are women, who are especially susceptible to many environmental hazards when pregnant, since the reproductive system is particularly sensitive to adverse environmental conditions. Research by Holland (2001) has shown that noise lowers birth weight, increases frequency of prematurity, and damages children's hearing while in utero.

4.2.2 Physical impairments

According to the World Health Organisation (2002), people with particular diseases or medical problems (e.g. high blood pressure), people in hospitals or rehabilitating at home, people dealing with complex cognitive tasks and people with disabilities such as hearing impairment or blindness, are particularly vulnerable to noise. People with impaired hearing are the most adversely affected with respect to speech intelligibility. According to the Health Council of the Netherlands, exposure of hospitalized patients to relatively high levels of noise delays recovery and wound healing (Basrur 2000).

4.2.3 Socio-economic conditions

According to Stansfeld et al. (2000), it is a well-known fact that social deprivation is associated with low school achievement. The effects of additional adverse environmental conditions such as noise may have a cumulative effect on low achievement in children from socially disadvantaged backgrounds. Therefore, children from disadvantaged backgrounds may be more vulnerable to the effects of chronic noise exposure than more advantaged children. Socially disadvantaged groups are also at much higher risk of suffering from health problems because they live and work with much higher levels of environmental stress factors like greater noise levels (Danish Agency for Development Assistance 2000).

The association between social deprivation and children's cognition or school performance and health is complex. Stansfeld et al. (2000) maintain that noise could be part of the explanation why social deprivation influences health and cognition, or, that noise causes the deficit in cognition or health and that it is made worse in a situation of social deprivation. Yet another explanation could be that social deprivation is the primary force in determining performance or ill health and that noise worsens the effect (Federal Interagency Committee on Aviation Noise 2000).

Indicators of social deprivation could be income, employment status, home/car ownership, household crowding and the type of dwelling. Individuals or households living in poor-quality homes constructed of poor materials are particularly vulnerable due to the lack of noise insulation these houses provide. This vulnerability can thus extend to a large share of the urban population in many cities.

4.3 VULNERABILITY TO AIRCRAFT NOISE EXPOSURE AT CAPE TOWN INTERNATIONAL AIRPORT

The following section aims to profile the exposed population around Cape Town International Airport according to vulnerability characteristics and to locate the vulnerable groups within the communities. Firstly, the neighbourhoods and population exposed to moderate, significant and severe noise levels is determined. After that, the vulnerable groups situated around the airport are identified and located, and the section concludes with the perceptions of the Uitsig community towards aircraft noise.

4.3.1 Neighbourhoods and population exposed to various intensities of aircraft noise

Firstly, the aircraft noise levels in DNL were classified according to noise exposure classes used by the Department of Housing and Urban Development in the USA. The new South African standards SANS 10117:2003 and SANS 10103:2003 were not available at the time of research. Future research should use these standards. The classification appears in Table 4.3 and ranges from minimal (<55) to severe (>75) noise exposure.

Table 4.3 Noise exposure classification

NOISE LEVEL (DNL)	NOISE EXPOSURE ZONE
<55	MINIMAL EXPOSURE
55-65	MODERATE EXPOSURE
66-75	SIGNIFICANT EXPOSURE
>75	SEVERE EXPOSURE

Source: Federal Interagency Committee on Urban Noise (2001b): 5

As indicated on Figure 4.1, no neighbourhoods are exposed to severe noise levels as this noise zone overlays the airport proper and a large portion of vacant land directly to the east of the airport. Portions of Philippi East, Delft South, Belhar, Bishop Lavis, Modderdam and an industrial area directly to the south of the airport are exposed to significant noise levels of 65-75DNL. The areas exposed to moderate noise levels are parts of Parow, Goodwood, Bellville, Matroosfontein, Delft, Crossroads, Mandalay, Philippi, Mitchells Plain and Khayelitsha.

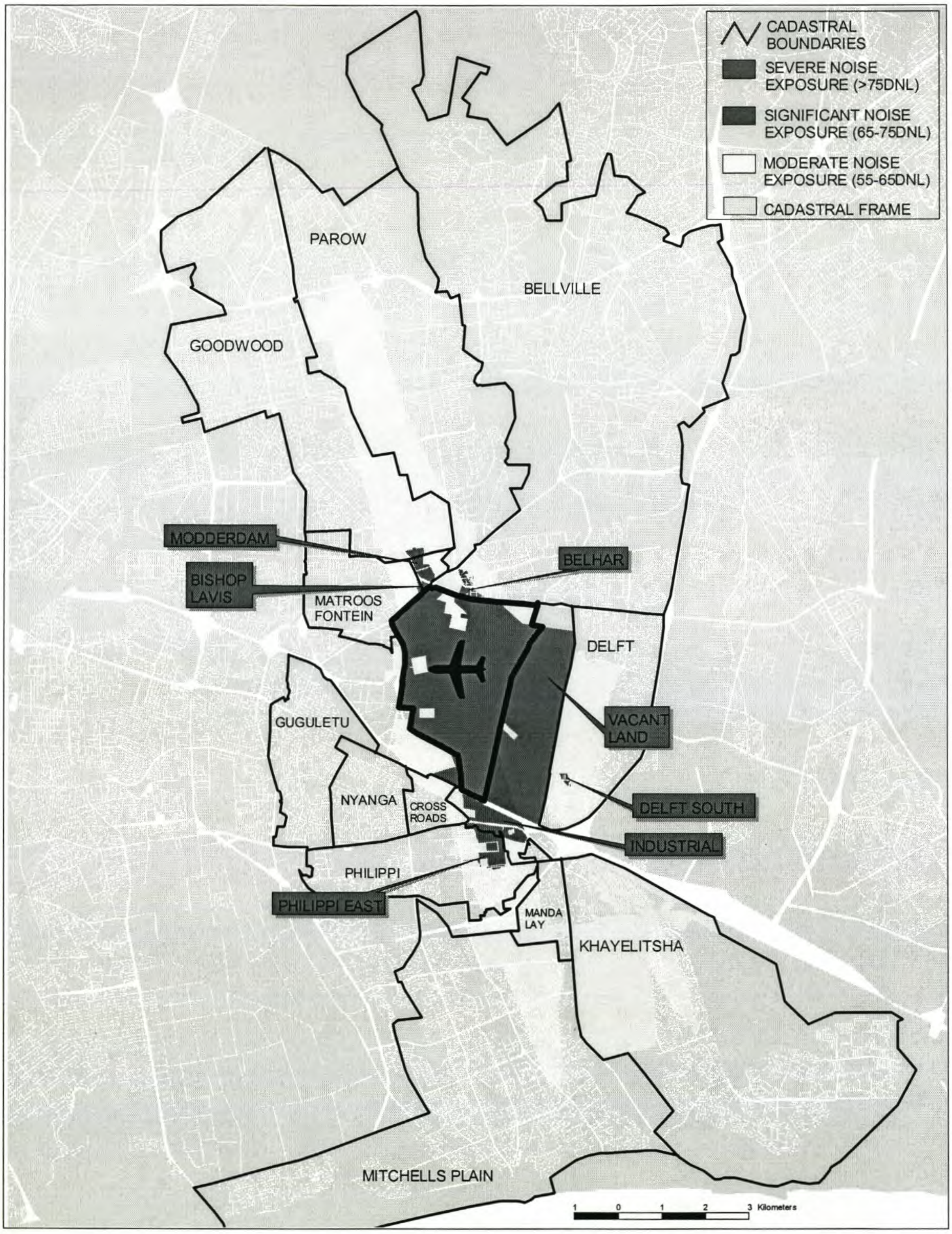

Figure 4.1 Neighbourhoods exposed to aircraft noise around Cape Town International Airport

The next step was to determine the population groups exposed to each noise exposure zone. Census enumerator areas with data from the 1996 census were intersected with the noise zones to obtain the number of people exposed in each zone. The population groups and the total number of people exposed is indicated in Table 4.4 and their location in Figure 4.2.

Table 4.4 Population groups exposed to various intensities of noise levels

	NUMBER OF PEOPLE PER POPULATION GROUP					
NOISE EXPOSURE ZONE	INDIANS/ASIANS	WHITES	BLACKS	COLOUREDS	UNSPECIFIED	TOTAL
SEVERE (>75)	0	0	0	0	0	0
SIGNIFICANT (65-75)	39	6	555	8980	295	9875
MODERATE (55-65)	4040	15647	81732	109167	3146	213732
TOTAL	4079	15653	82287	118147	3441	223607

As mentioned previously, no people are exposed to severe noise levels, as this zone overlays the airport proper, which contains no residential areas. Almost 10 000 people are exposed to significant noise levels, with the Coloured population having the largest number of people exposed in this zone. Almost a quarter of a million people are exposed to moderate noise levels, with the largest group affected also being the Coloured population. The population groups situated around CTIA are segregated, with the Whites and Asians located north of the airport, the Blacks mostly south of the airport and the Coloureds both north and south of the airport.

4.3.2 Vulnerable groups

Three different types of vulnerable groups were identified according to demographics, physical factors and socio-economic factors. Table 4.5 lists the number of people affected in each group and each of the next three subsections focuses on one characteristic of vulnerability. Reference will continually be made to this table.

Table 4.5 Vulnerable groups in the noise-affected zone

VULNERABLE GROUP	SIGNIFICANT NOISE EXPOSURE	MODERATE NOISE EXPOSURE	TOTAL
Demographically disadvantaged:			
Children (0-16 years old)	3592	75222	78814
Elderly (≥65 years old)	345	6673	7018
Women	5063	110421	115484
Physically disadvantaged:			
Hearing disability	33	1364	1367
Sight disability	57	3544	3601
Socially disadvantaged:			
Low income (0-R500/month individual)	6010	130838	136848
Unemployed	967	25651	26618
Poor quality dwelling: traditional dwelling/hut	0	192	192
Poor quality dwelling: shack	719	17569	18288
Poor quality dwelling: caravan/tent	2	67	69

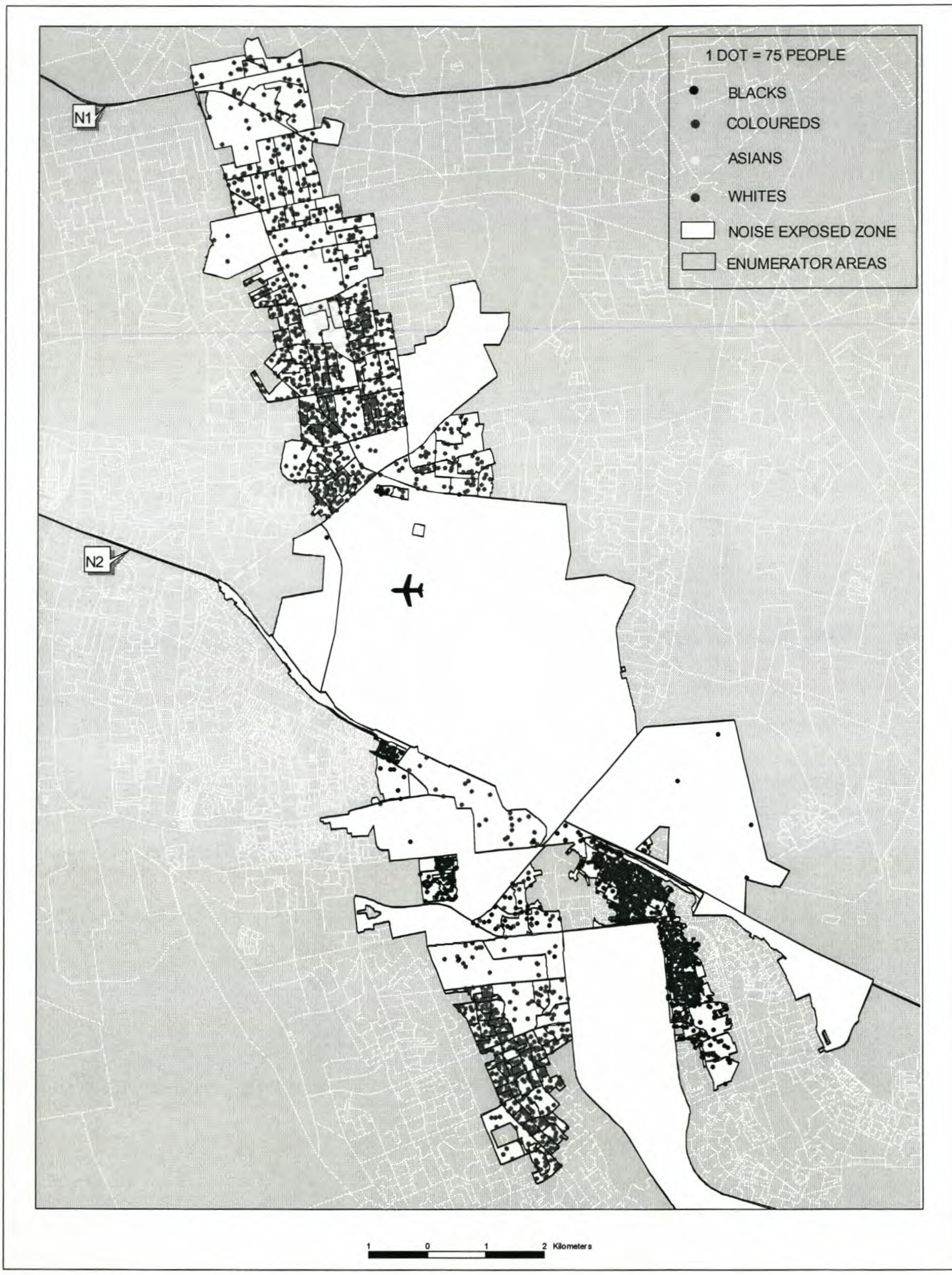

Figure 4.2 Location of population groups exposed to various intensities of noise levels

4.3.2.1 Demographically disadvantaged

The demographically disadvantaged group includes children (0–16 years old), the elderly (65 years or older) and women. Children and the elderly as a proportion of the total population in the affected noise zone is shown in Figure 4.3.

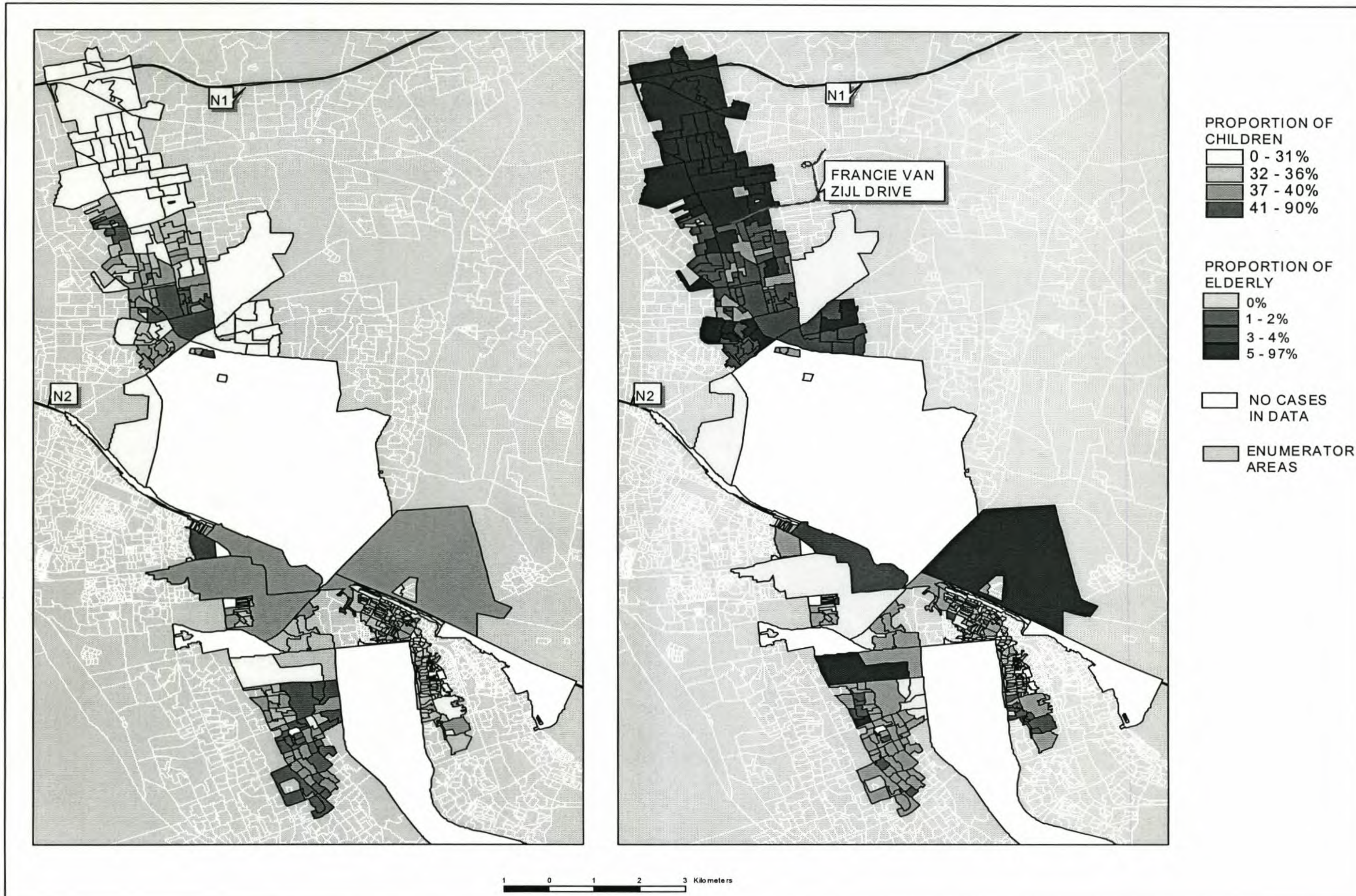

Figure 4.3 Proportion of children and elderly in the noise exposed area

Almost 80 000 children are affected by moderate and significant noise levels with a high proportion located in the census enumerator areas to the south of the airport below the N2. Just over 7000 people over the age of 65 years are located in the noise-exposed area with a large proportion located to the north of the airport between the N1 highway and Francie Van Zijl Drive. The proportion of women in the total population is more or less even across the noise-exposed area and was therefore not mapped. There are nevertheless more than 200 000 demographically disadvantaged people in the zone.

4.3.2.2 Physically disadvantaged

The next vulnerable group consists of some 5000 people that are physically disadvantaged, either with hearing impairments or sight disabilities. Approximately 700 people with hearing disabilities and 2000 with sight disabilities are located south-east of the airport in Khayelitsha in the moderate noise exposure zone as indicated in Figure 4.4.

4.3.2.3 Socially disadvantaged

The third vulnerable group is the socially disadvantaged and these were considered in two distinct groups: income and employment related and dwelling type related. Social disadvantage or deprivation can be indicated by a number of factors. The individual indicators used in this study were income, employment and type of dwelling. The lowest three tiers of individual income classification in the 1996 census were No income, <R250 and R251- R500 and these were selected to represent those individuals in the low income group. All those who were unemployed and looking for work were included, but not those who were not looking for work, not wishing to work, housewives, pensioners, scholars or the disabled. More than 160 000 people fall in these two categories in the affected zone as depicted in Figure 4.5. Most of the people in the low-income and unemployed categories are located to the south-east of the airport in Khayelitsha.

With regards to the type of dwelling, those categories offering insufficient insulation to aircraft noise e.g. huts, shacks and caravans/tents were selected. The most predominant of the above mentioned dwelling types in the noise exposure zone are the more than 18 000 shacks. Large numbers of shacks are found in the southern part of Uitsig, the eastern part of Bishop Lavis and in parts of Khayelitsha as demonstrated by Figure 4.6.

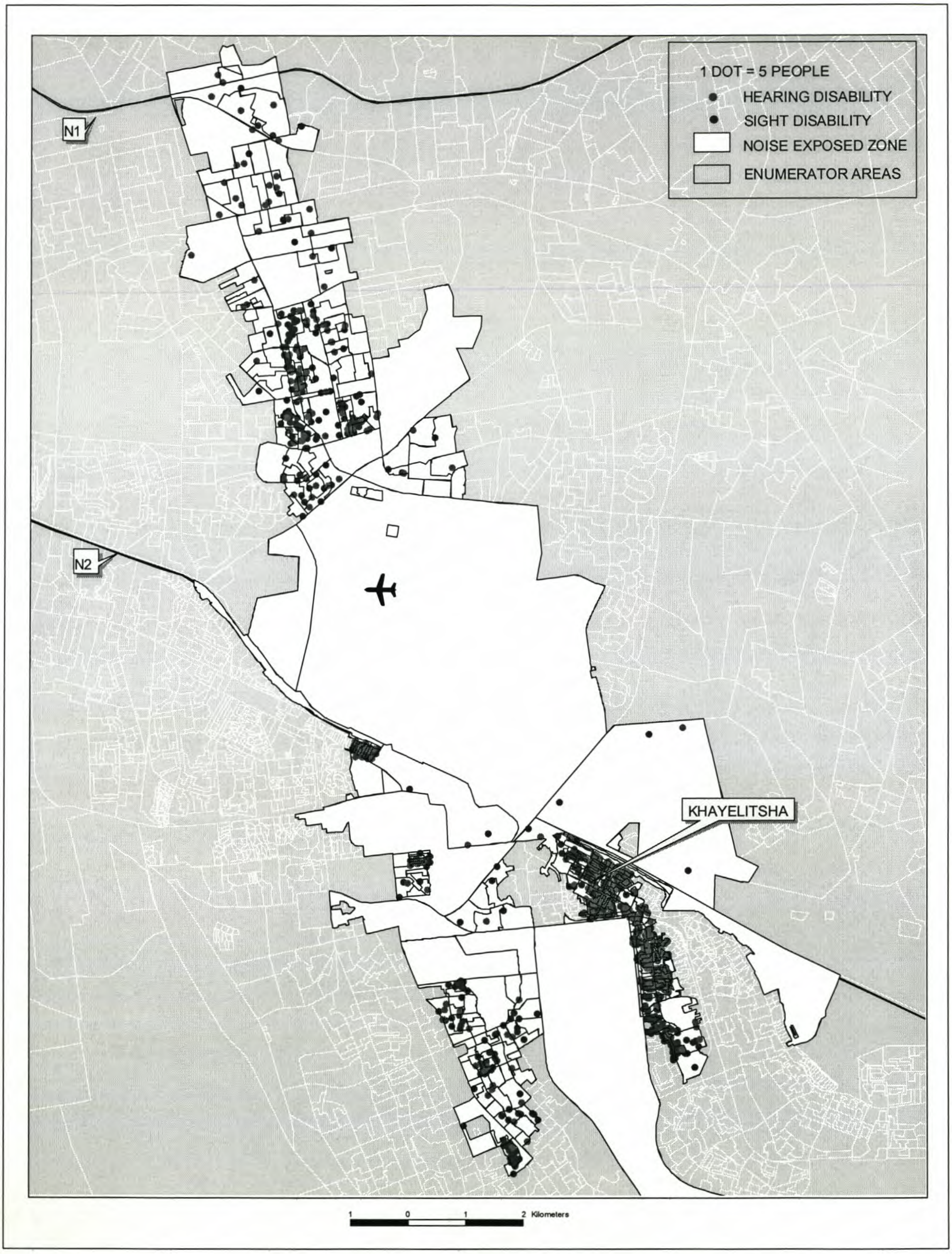

Figure 4.4 Location of people with hearing and sight disabilities in the exposure zone

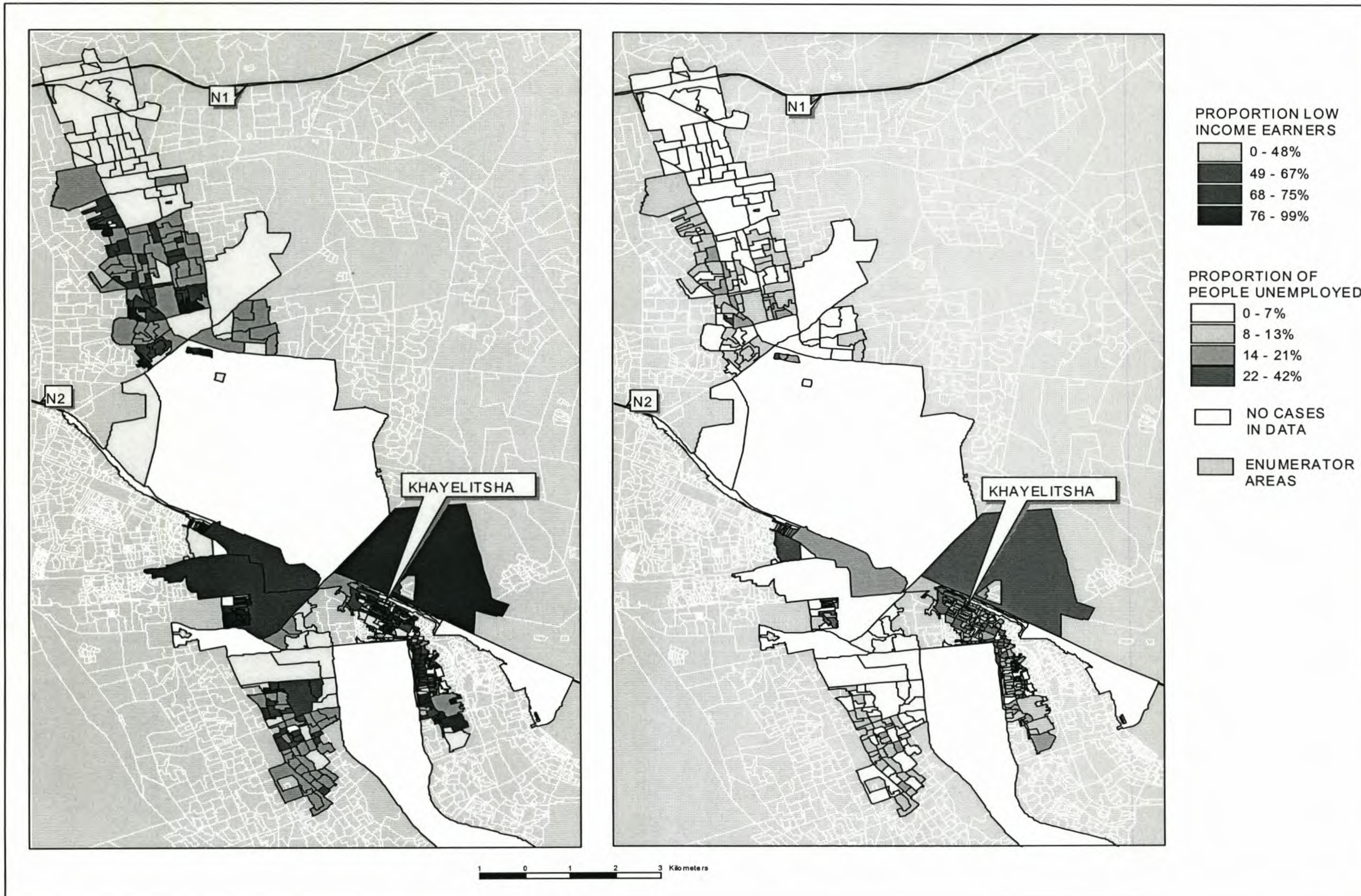

Figure 4.5 Proportion of low-income earners and unemployed in the exposure zone

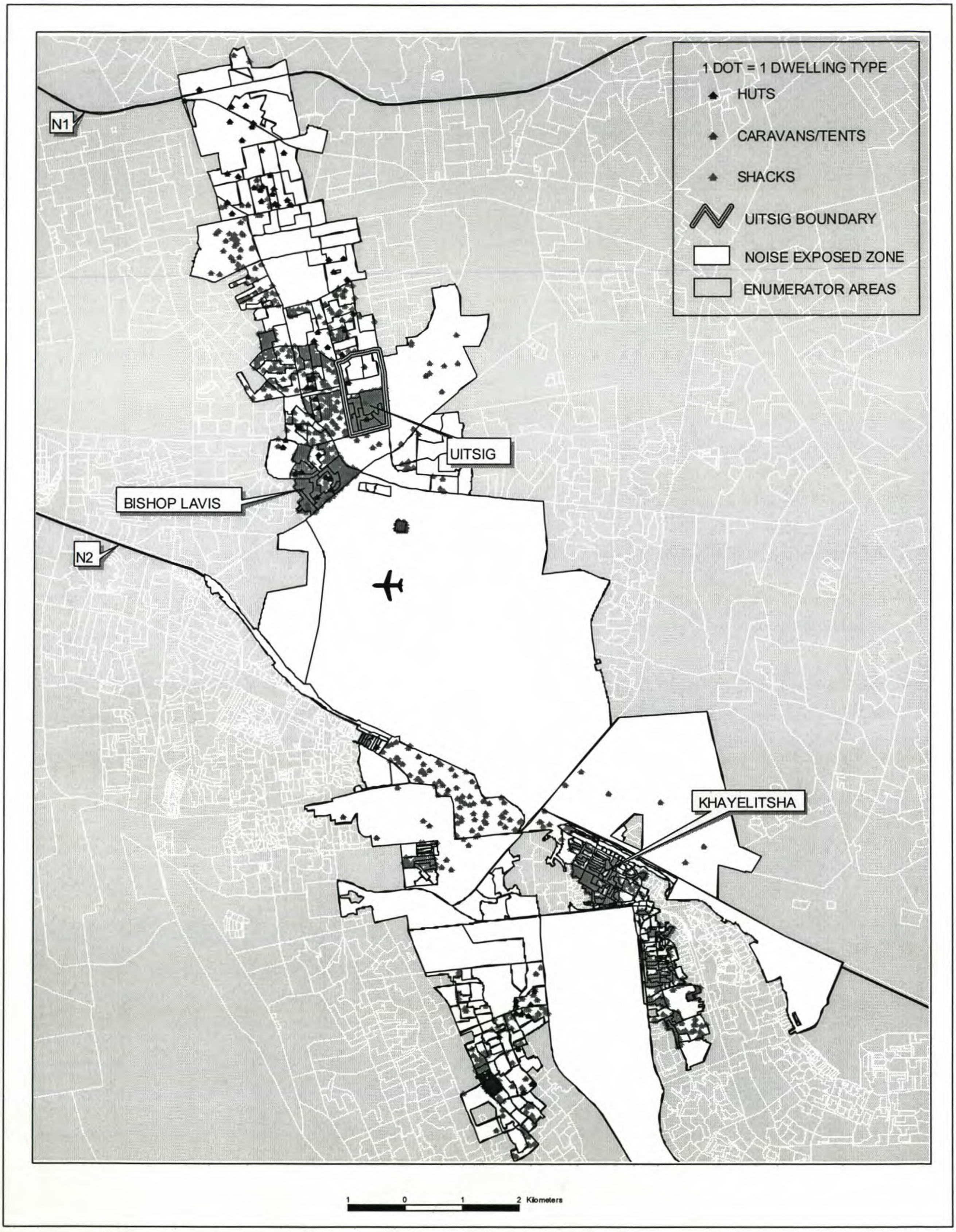

Figure 4.6 Location of poor quality dwellings in the exposure zone

4.3.3 Perceptions about aircraft noise from the Uitsig community

It was beyond the scope of this study to formally determine how the communities situated around Cape Town International Airport perceive aircraft noise, so the Uitsig Urban Renewal Strategy was consulted to get an indication of how the community in Uitsig experience aircraft noise. Uitsig is an extremely impoverished suburb located about 2 km north of Cape Town International Airport as indicated on Figure 4.6, and falls within the moderate noise exposure zone. The results of the above socio-economic survey undertaken indicated that aircraft noise is a factor in the overall quality of life of the communities and 79% of the community feel that the degree of impact is 'significant' as opposed to 'intermediate' or 'barely noticeable'. According to one resident, every time an aircraft flies over the house the television loses its signal and the house shakes. The residents also felt that the houses in Uitsig were poorly equipped to provide any insulation against aircraft noise (City of Cape Town 2001). It is therefore clear that, even in low socio-economic status neighbourhoods, aircraft noise is a serious problem and perceived as such.

4.4 CONCLUSION

In South Africa, communities situated close to airports often have more pressing problems to deal with than aircraft noise, and can be expected to grudgingly tolerate a noisy home environment if this is the only place where they can locate their homes. According to Johnston (1989:10), this apparent apathy is more likely a manifestation of Maslow's hierarchy of needs: "A community will remain relatively insensitive to noise as long as its more basic needs, such as food, shelter, security and employment are not adequately met." It can be hoped that the more basic needs will be satisfied ultimately, but in the mean time vulnerable communities should be identified and measures such as improving the quality of housing, infrastructure and services put in place to reduce this already exposed vulnerability.

CHAPTER 5: SYNTHESIS

This chapter is a synthesis of all the research results and begins with a summary of the objectives and an evaluation of results. It concludes with planning recommendations derived from the research, suggestions for future research and some concluding directives on noise as an environmental problem.

5.1 RESEARCH OBJECTIVES REVISITED

The aim of this study was to employ GIS to establish the potential noise exposure of various sensitive land use categories and population groups in the noise-controlled area at Cape Town International Airport, according to the DNL noise contours. The results and evaluation of each specific objective formulated to achieve this aim can now be considered.

The **first objective** was to demarcate a "controlled area" based on the 65DNL noise contour for the year 2015, by identifying on the ground the extent of this area. This objective was realized through six different demarcation options for the "controlled area", each consisting of a different combination of underlying datasets and GIS methods. The datasets used were cadastral erven, streetblocks and enumerator areas, and the GIS methods included intersection and buffering. The demarcation options were rated in terms of the ease of the GIS procedure used, the resulting size of the area in terms of the social, economic and legal implications, the practicality of the spatial unit used and the international support found for the option. Consequently, the research showed the best method of demarcating the "controlled area" to be Option 1A where all the property units (cadastral erven) that intersect with the polygon formed by the 65DNL noise contour are selected.

The **second and third objectives** were to build a GIS database of land use types in the noise-controlled area, classify land use types according to noise sensitivity levels, and identify incompatible land uses and priority areas for land use compatibility projects. These objectives were reached successfully. Land use types were classified by assigning maximum noise levels allowed for each land use type, according to the land use compatibility table drafted by the town planners. The conservative (no acoustical screening) option identified the largest number of incompatible cases due to the large amount of high-density residential land use located in the high noise zones. The two areas with the highest priority rating are both high-density residential areas located in Delft and Philippi. The land use types that constitute the priority areas identified include residential, educational, religious activities, hospitals, community halls, offices and high intensity retail. A recommendation made for a land use action plan for CTIA was that urban renewal projects for priority areas should be initiated. These projects could include relocating communities in informal high-density residential areas or, if this were not possible, improving the physical living conditions and housing structure of these areas, to ensure more effective insulation from aircraft noise.

The **fourth objective** was to profile the exposed population in the noise-controlled area by demographic, physical and socio-economic vulnerability characteristics and to locate vulnerable groups. The first task, to identify the neighbourhoods and population exposed to severe, significant and moderate noise exposure levels was completed successfully. It was found that no people are exposed to severe noise levels, as this zone overlays the airport, which contains no residential areas. Portions of Philippi East, Delft South, Belhar, Bishop Lavis, and Modderdam are exposed to significant noise levels with the Coloured population having the largest number of people exposed in this zone. Parts of Parow, Goodwood, Bellville, Matroosfontein, Delft, Crossroads, Mandalay, Philippi, Mitchells Plain and Khayelitsha are exposed to moderate noise levels with almost a quarter of a million people affected in this zone, with the largest group affected also being the Coloured population.

The vulnerable groups were divided into three types: those influenced by demographic, physical and socio-economic factors. The demographically disadvantaged group, of which there are more than 200 000 in the noise-affected zone, includes children, the elderly and women. A high proportion of children are located south of the airport and the N2, while a high proportion of elderly are located north of the airport below the N1. The proportion of women is more or less evenly distributed across the noise-exposed area. Most of the physically disadvantaged group, either with hearing impairments or sight disabilities, is located south-east of the airport in Khayelitsha in the moderate noise exposure zone. The third vulnerable group is the 160 000 socially disadvantaged, indicated by income, employment and type of dwelling.

Most of the people in the low-income and unemployed categories are located to the south-east of the airport in Khayelitsha in the moderate noise exposure zone. All dwelling types offering insufficient insulation to aircraft noise like huts, shacks and caravans/tents were selected, with the most predominant dwelling types in the moderate and significant noise exposure zone being the more than 18 000 shacks. Large numbers of shacks are found in the southern part of Uitsig, the eastern part of Bishop Lavis and in parts of Khayelitsha.

5.2 PLANNING RECOMMENDATIONS FOR CTIA

As mentioned in Chapter 3, community involvement is an important part of airport noise compatibility planning and in the management of airport noise issues as a whole. Direct public participation gives the communities a better understanding of the potential environmental effects of the airport. This can be achieved through the use of GIS, which 'empowers citizens by providing them with a dynamic and interactive tool for improved participation' (Calinao & Brennan 2002:37). The value of geographic information and the power of GIS applications to solve problems are proportional to their accessibility (Harder 1998). This is where the Internet has a tremendous influence on GIS in that it increases the accessibility thereof. 'Internet GIS ... allows citizens to access and interact with mapping and GIS data to enhance their knowledge [about airport development and noise issues] and increases their participation in the overall environmental decision-making process' (Calinao & Brennan 2002:37).

A recommendation from this research is that CTIA, the City of Cape Town or the airlines and aircraft operators should set up an interactive map-based website to disseminate information about noise and any other important issues concerning the airport to the public. When construction on the new runway commences, many questions will arise from the public about the effects of this development. An Internet GIS application can be designed to help the public better understand the proposed developments as well as the attendant potential environmental and socio-economic effects.

From 1 January 2003 ACSA is responsible for setting up noise monitoring stations around the airport and, once these are in place the noise data gathered from the monitoring stations can be made available to the public through the website. Another potential use of the website is that it can be used to log noise complaints from the public. With the noise data received from the monitoring stations, complaints can be evaluated against actual activities of aircraft, each noise complaint investigated, and prompt feedback given to the communities complaining about aircraft noise.

5.3 SUGGESTIONS FOR FURTHER RESEARCH

Further research needs to be conducted into the possibility of integrating computerized noise models and GIS. Noise levels are computed in separate specially developed computer simulation models, and the GIS has been used in noise mapping mainly to quantify and visualise noise effects because of the spatial tools, extended spatial database, advanced noise contour interpolation methods and computation power GIS offers. The noise calculation method could be implemented in the GIS, making conversion and exporting data between the systems unnecessary. Existing GIS techniques and functions to process spatial data could be used to optimise the calculation process. Although De Kluijver & Stoter (2001) maintain that implementing the noise calculation method in GIS and "replacing" the existing software could be difficult, since the existing noise computer models have a status of confidence, the researcher is convinced that the topic would benefit from further research.

Another suggestion for further research could be the calculation of an index of overall aircraft noise impact. The individual vulnerability indicators such as age, gender, disability, income, employment and dwelling type could be combined with the priority areas of highest noise sensitivity to create a composite index of overall noise impact at CTIA and other airports around South Africa.

It would also be beneficial to find out how people in close proximity to Cape Town International Airport perceive aircraft noise and what the social implications of these perceptions are. A perception study could be done at CTIA with a follow-up study at the other large airports in South Africa to see if there is a difference in people's perceptions around the country. Transport Minister Dullar Omar stated at the Ninth Aviation and Allied Business Conference in Sandton in August 2003 that, "In Europe, the sound of an aircraft approaching is merely noise, but in Africa it could be the sound of hope" (Sunday Times 2003). It would be interesting to find out if the people of South Africa agree with him.

5.4 CONCLUSION

In truth, there are perhaps far graver environmental threats facing our planet than noise. Among these threats are extinction, global warming, waste and overpopulation. Noise problems are comparatively less serious, but this does not mean that noise should be neglected while solutions are sought for the greater threats. At the local community level where people are being annoyed every day and night resulting in negative health effects, the problem demands urgent attention.

Aircraft noise pollution is a factor that airlines, town planners, government bodies, environmental institutions, communities affected and, therefore, researchers too cannot afford to ignore. It is a multi-faceted phenomenon and the unique nature of noise as a pollutant presents us with very complex technical, environmental, social, political and legal issues and implications for our country.

REFERENCES

Abeyratne RIR 1994. Aircraft engine emissions and noise. *Environmental Policy and Law* 24, 5:238-250.

Airports Company of South Africa 2000. Cape Town International Airport. Master Plan Update. Johannesburg: ACSA.

Airports Company of South Africa 2001. Cape Town International Airport. Development Framework. Volume one. Cape Town: ACSA.

Airports Company of South Africa 2003. Cape Town International Airport. [Online]. Available http://www.airports.co.za/home [Accessed 12.08.2003].

Anthrop D 1973. *Noise Pollution*. Lexington: Lexington Books.

Australian Department of Transport and Regional Services (ADTRS) 2002. Airport noise insulation eligibility criteria. [Online]. Available https://secure.dotars.gov.au/anip/information/anip-eligibility.cfm [Accessed 1.10.2002].

Basrur SV 2000. Health effects of Noise. City of Toronto: Community and Neighbourhood Services. [Online]. Available http://www.city.toronto.on.ca/health/hphe/pdf/noiserpt attachment march23.pdf [Accessed 20.11.2002].

Bryant WA 2000. Airport noise abatement and compatible land use planning: A case study of Seattle-Tacoma International Airport. In Miller D & De Roo G (eds.) *Resolving urban environmental and spatial conflicts,* pp77-87. Groningen: Geo Press.

Bugliarello G, Alexandre A, Barnes J & Wakstein C 1976. *The impact of noise pollution: A socio-technological introduction.* New York: Pergamon Press.

California Department of Transportation 2002a. Airport land use planning handbook – Establishing airport noise compatibility policies. [Online]. Available http://www.dot.ca.gov/hq/planning /aeronaut/htmlfile/landuse.html [Accessed 27.5.2002].

California Department of Transportation 2002b. Airport land use planning handbook – Formulating airport land use compatibility policies. [Online]. Available http://www.dot.ca.gov/hq/ planning/aeronaut/htmlfile/landuse.html [Accessed 27.5.2002].

Calinao B & Brennan C 2002. Power to the people: A web-based GIS provides a public-involvement tool for airport development. *GeoWorld* June 32-37.

City of Cape Town 2001. Uitsig: Urban renewal strategy. Second draft. Cape Town: Tygerberg Administration.

City of Grand Junction Colorado 2002. Zoning and development code manual. [Online]. Available http://www.gjcity.org/CityDeptWebPages/CommunityDevelopment/DevelopmentServices/ ZoningCode.htm [Accessed 10.8.2002].

Cunniff PF 1977. *Environmental noise pollution*. New York: Wiley.

Danish Agency for Development Assistance 2000. Who suffers? Identifying vulnerable groups. Workshop on improving urban environment and reducing poverty. Copenhagen, Denmark. [Online]. Available http://web.mit.edu/urbanupgrading/urbanenvironment/issues/vulnerable-groups.html [Accessed 10.11.2002].

De Kluijver H & Stoter J 2001. Noise mapping and GIS: optimizing quality and efficiency of noise effect studies. *Computers, Environment And Urban Systems* 27, 1:85-102.

De-Roo G & Bartelds H 1996. Quiet Areas: A noble failure? *Town Planning Review* 67, 1:87-95.

Federal Interagency Committee on Aviation Noise 2000. FICAN Position on research into effects of aircraft noise on classroom learning. [Online]. Available http://www.fican.org/ Effects_ aircraft.pdf [Accessed 10.11.2002].

Federal Interagency Committee on Urban Noise 2001a. Aircraft noise overlay district. [Online]. Available http://www.wyleacoustics.com/acpdfs/orlandzo.pdf [Accessed 12.6.2002].

Federal Interagency Committee on Urban Noise 2001b. Land use compatibility guidelines [Online]. Available http://www.wyleacoustics.com/acpdfs/landucomp.pdf [Accessed 12.6.2002].

Green DM & Fidell S 1991. Variability in the criterion for reporting annoyance in community noise surveys. Journal of the Acoustical Society of America 89, 1:234-243.

Goodall B 2000. Planning and pollution abatement: A role for environmental auditing. In Miller D & De Roo G (eds.) *Resolving Urban Environmental and Spatial Conflicts,* pp 153-171. Groningen: Geo Press.

Hadzilacos T 1996. On layer-based systems for undetermined boundaries. In Burrough PA & Frank AU (eds). *Geographic Objects with Indeterminate Boundaries,* pp 237-254. London: Taylor and Francis.

Harder C 1998. *Serving Maps on the Internet.* Redlands: ESRI.

Holland W 2001. The health effects of aircraft noise. [Online]. Available http://www.geocities.com/RainForest/Jungle/6748/health.html [Accessed 9.11.2002].

Johnston CJ 1989. Noise control in a changing South Africa. *SABS-Bulletin* 8, 8:11-15.

Krynauw SJ 2002. Demarcation of "Controlled Area". Unpublished Progress Report for Cape Town International Airport Development Framework. Volume one. City of Cape Town: Tygerberg Administration.

Kryter KD 1994. *The handbook of hearing and the effects of noise.* San Diego: Academic Press.

Mato RR & Mufuruki TS 1999. Noise pollution associated with the operation of the Dar es Salaam International Airport. *Transportation Research Part D: Transport and Environment* 4, 2:81-89.

McNerney MT 1994. Use of GIS at U.S. Airports. Urban and Regional Information Association. [Online]. Available http://www.odyssey.maine.edu/gisweb/spatdb/urisa/ur94061.html [Accessed 20.6.2002].

Mestre V 2001. Single event noise metrics. Federal Interagency Committee on Urban Noise [Online]. Available http://www.fican.org.download.semetrics.pdf [Accessed 1.10.2002].

Metropolitan Airports Commission 2002. Minneapolis St Paul residential sound insulation program. Department of Transport. [Online]. Available http://www.macavsat.org/part150/sound_insulation/index.htm [Accessed 12.5.2002].

Miedema HME 2001. Noise and health: How does noise affect us? The 2001 International Congress on Noise Control Engineering. [Online]. Available http://www.health.tno.nl/wie_we_zijn/organisatie/divisies/volksgezondheid/milieufolder/in01_740.pdf [Accessed 4.10.2002].

Pereira Filho AJ, Braaksma JP & Phelan JJ 1995. Interpreting airport noise contours. *Transportation Research Record* 1475:66-69.

Prescott GW 1994. The practitioner's guide to GIS terminology: A glossary of geographic information system terms. Washington: Data West Research Agency.

Rhodes DP & Ollerhead JB 2001. Aircraft noise model validation. The International Congress and Exhibition on Noise Control Engineering. [Online]. Available http://www.macavsat.org/part150/inm_valide.htm [Accessed 28.9.2002].

Robertson V 1989.The South African aircraft noise prediction procedure. *SABS-Bulletin* 8, 11:5-11.

Rowe M & Caraway M 1998. GIS enhances noise abatement program: LAWA (Los Angeles World Airports) uses GIS to comply with state noise regulations. *Earth Observation Magazine* 7, 3:12-14.

Schaller J 1990. Geographical information system applications in environmental impact assessment. In Scholten HJ & Stillwell JCH (eds.) *Geographical information systems for urban and regional planning*, pp 119-128. Dordrecht: Kluwer Academic Publishers.

Schneider M 1996. Modelling spatial objects with undetermined boundaries using the Realm/Rose Approach. In Burrough PA & Frank AU (eds). *Geographic objects with indeterminate boundaries,* pp141-152. London: Taylor and Francis.

South African Department of Transport 1998. White Paper on national policy on airports and airspace management. [Online]. Available :http://www.gov.za/whitepaper/airport_wp.html [Accessed 19.6.2002].

South African Department of Transport 1999. Draft National policy on aircraft noise and engine emissions. Final policy document. Second draft. Pretoria: DOT.

South African Department of Transport 2002. Draft National policy on aircraft noise and engine emissions. Unofficial update. Pretoria: DOT.

Standards South Africa 2003. SANS 10117:2003. Calculation and prediction of aircraft noise around airports for land use purposes. Pretoria: SABS.

Standards South Africa 2003. SANS 10103:2003. The measurement and rating of environmental noise with respect to land use, health, annoyance and to speech communication. Pretoria:SABS.

Stansfeld S, Haines M, Brentnall S, Head J, Roberts R, Berry B & Jiggins M 2000. Aircraft noise at school and children's cognitive performance and stress responses. UK Department of Health. [Online]. Available http://www.doh.gov.uk/airpollution /finrepwlondon schools. pdf [Accessed 20.10.2002].

Stusnick E, Thompson RL, Evans BA & Difelici J 1998. Aircraft community noise impact model. *Transportation Research Record* 1626:58-67.

Sunday Times 2003. Aviation key to Africa's development: Omar. 12.08.03 [Online]. Available www.suntimes.co.za/business [Accessed 11.08.2003].

Tempest W (ed.) 1985. *The noise handbook*. London: Orlando Academic Press.

Tomkins J, Topham N, Twomey J & Ward R 1998. Noise versus access: The impact of an airport in an urban property market. *Urban Studies* 35, 2:243-258.

Transportation Research Board 1997. Aircraft noise modelling. *Transportation Research Circular* 473 ISSN 0097-8515 Washington DC: National Research Council.

U.S. Department of Commerce 1985. Aviation noise effects. Federal Aviation Administration [Online]. Available http://www.nonoise.org/library/ane/ane.htm [Accessed 01.06.2001].

U.S. Department of Transportation 1999. Land use planning initiatives. Federal Aviation Administration [Online]. Available http://www.aee.faa.gov/noise/LUPI.htm [Accessed 25.6.2002].

U.S. Department of Transportation 2000a. Aviation noise abatement policy. Federal Aviation Administration [Online]. Available http://www.faa.gov/programs/en/impact/1976ANAP/index.htm [Accessed 7.6.2002].

U.S. Department of Transportation 2000b. Aircraft noise – The next standard. Federal Aviation Administration: Office of Environment and Energy. [Online]. Available http://www.useu.be/aircr0419.html [Accessed 4.9.2002].

U.S. Department of Transportation 2002a. Integrated noise model. Federal Aviation Administration: Office of Environment and Energy. [Online]. Available http://www.aee.faa.gov/noise/INM.htm [Accessed 25.6.2002].

U.S. Department of Transportation 2002b. Day-night average sound level. Federal Aviation Administration: Office of Environment and Energy. [Online]. Available http://www.aee.faa.gov/noise/DNL.htm [Accessed 25.6.2002].

Voogd H 2000. Urban environmental pollution: Perception and compensation. In Miller D & De Roo G (eds.) *Resolving urban environmental and spatial conflicts,* pp91-102. Groningen: Geo Press.

World Health Organisation 2002. Guidelines for community noise. [Online]. Available http://www.who.int/environmental_information/Noise/ComnoiseExec.htm [Accessed 12.11.2002].

PERSONAL COMMUNICATIONS

Swanepoel P 2002. Chairperson. Association of Municipal Town & Regional Planners. E-mail on 28 August 2002 about the aircraft noise land use compatibility table.

Krynauw SJ 2002. Airport coordinator. City of Cape Town. E-mail on 26 August 2002 about insulation of houses in noise sensitive areas.

APPENDIX A

Table A.1 Land uses not classified

CATEGORY	REASON WHY NOT REGARDED AS A LAND USE TYPE
Partially vacant land	Should be categorised according to the non-vacant part of the premises.
Resorts/camps	This category can be divided into the residential component, which falls under the temporary residential category and the rest as per specific use, eg. sport, offices, wilderness area etc.
Military, Air Force, Navy & Army	This category can be divided into the residential component, which falls under the high density residential and the rest as per specific use, eg. sport, offices, wilderness area etc.
All Government Departments	Government departments will have a use already listed and must be categorised according to that use.
Under demolition or construction/reconstruction	This category is a temporary use and should be categorised according to the permanent use.

Table A.2 Noise sensitivity classification of land use types

LAND USE CATEGORY OF DATA GIVEN	CORRESPONDING LAND USE TYPE IN COMPATIBILITY TABLE	CONSERVATIVE OPTION (max in DNL)	LIBERAL OPTION (max in DNL)	NOTES
Housing (Formal)	Low density residential	65	65	
Housing (Informal)	High density residential	55	60	
Housing (Backyard shelters & shacks)	Medium density residential	60	60	
Housing (Flats)	High density residential	55	60	
Housing (Institutional)	High density residential	55	60	
Housing (Tourist/ Temporary Accommodation)	Temporary residential	65	70	
Nature Reserves	*Agriculture-crop/ cattle farming	*75	*75	*Game/bird reserves the same principle as cattle farming and flower reserves the same as crop farming.
Water Areas/Wetlands	*Vacant land	*80>	*80>	*Same principle as vacant land except if it's a nature reserve.
Wilderness Areas	Agriculture-cattle farming	75	75	
Public Open Spaces	Picnic facilities	75	75	
Agriculture	Agriculture-crop/ cattle farming	75-cattle/ 80-crops	75-cattle/ 80-crops	
Forestry	Agriculture-crop farming	80	80	
Fisheries	Agriculture-cattle farming	75	75	
Mining & Quarrying	Manufacturing	75	75	
Manufacturing (Food)	Manufacturing	75	75	
Manufacturing (Clothing, textiles & leather)	Manufacturing	75	75	
Manufacturing (Wood, Cork & Paper Production)	Manufacturing	75	75	
Manufacturing (Publishing & Printing)	Manufacturing	75	75	
Manufacturing (Petroleum, Chemicals, Pharmaceuticals & Soap)	Manufacturing	75	75	
Manufacturing (Glass, Ceramics & other non-metallic minerals)	Manufacturing	75	75	
Manufacturing (Metal products)	Manufacturing	75	75	

Manufacturing (Office, Accounting & Computer Equipment)	Manufacturing	75	75	
Manufacturing (Machinery & Equipment)	Manufacturing	75	75	
Manufacturing (Radio, TV & Telecommunications Equipment)	Manufacturing	75	75	
Manufacturing (Medical Precision Instruments, Optical Equipment & Watches)	Manufacturing	75	75	
Manufacturing (Transport Equipment)	Manufacturing	75	75	
Manufacturing (Furniture)	Manufacturing	75	75	
Manufacturing (Personal Goods)	Manufacturing	75	75	
Recycling	Manufacturing	75	75	
Manufacturing (Other)	Manufacturing	75	75	
Gas & Electricity supply	Manufacturing	75	75	
Water supply	Vacant land	80>	80>	
Vacant Land	Vacant land	80>	80>	
Partially vacant land	*Not regarded as a land use*	*see notes*	*see notes*	*No land uses of this category in the area.*
Vacant premises	Vacant land	80>	80>	
Under demolition or contruction/reconstruction	*Not regarded as a land use*	*see notes*	*see notes*	*Used zoning values.*
Wholesale & Commision Trade	Whole sale	75	75	
Retail (department)	*High intensity retail/ food & drink retail	*65	*70	*Identified the food & drink retail=70&75, others =65&70
Retail (specialised)	*High intensity retail	*65	*70	*Went for the most protected option i.e 65
Retail (informal)	*High intensity retail	*65	*70	*Went for the most protected option i.e 65
Repair of Personal & Household goods	Repairing	75	75	
Galvanising, sandblasting	Manufacturing	75	75	
Repair & Maintenance of motor trade	Motor trade and related uses	75	75	
Retail (motor trade)	Motor trade and related uses	75	75	
Resorts/Camps	*Not regarded as a land use*	*see notes*	*see notes*	*No land uses of this category in the area.*
Eating & Drinking Establishments	Restaurant, fast food,pub etc.	65	70	
Roads	Vacant land	80>	80>	
Rail Transport	Vacant land	80>	80>	
Road Transport Facilities	Bus, municipal & other depots	75	75	
Marine Transport	Vacant land	80>	80>	
Air Transport	Direct airport uses (passengers/cargo)	(passengers-65) /cargo-75	(passengers-75) /cargo-75	
Covered Parking	Parking garage	80	80	
Open Parking	Parking garage	80	80	
Warehousing/storage	Warehousing	75	75	
Communications	Offices	65	75	
Transport & Communication (Other)	Transport company	75	75	
Banks & Building Societies	Offices	65	75	
Insurance, Pension & Medical Aid	Offices	65	75	
Offices/Professional & Business Services	Offices	65	75	
All Goverment Departments	*Not regarded as a land use*	*65*	*75*	*Same principle as offices applied.*
Judicial facilities	Offices	65	75	

Military, Air Force, Navy & Army	*Not regarded as a land use*	*see notes*	*see notes*	*No land uses of this category in the area.*
Police Station	Offices	65	75	
Fire Station	Offices	65	75	
Education (Pre-primary)	Educational	60	65	
Education (Primary)	Educational	60	65	
Education (Secondary)	Educational	60	65	
Education (Tertiary)	Educational	60	65	
Education (Specialised training & schooling)	Educational	60	65	
Education (Other)	Educational	60	65	
Health (Hospitals)	Hospital, clinic	60	65	
Health (Special Care)	Hospital, clinic	60	65	
Health (Health Care Practices)	Other medical	60	65	
Health (Ambulance Service)	Other medical	60	65	
Health (Primary Health Care)	Hospital, clinic	60	65	
Health (Other)	Other medical	60	65	
Sewage/Stormwater Facilities	Vacant land	80>	80>	
Solid Waste Disposal	Vacant land	80>	80>	
Religious Activities	Church and other places of worship	60	65	
Entertainment facilities	Entertainment	65	70	
Cultural activities	Exhibition centre	70	75	
Library	Community hall, library etc.	65	70	
Sport Activities	Sport & recreation (high/low intensity)	*high intensity-65 (low intensity-80)	*high intensity-65 (low intensity-80)	Couldn't distinguish between intensity in the data so made all 65(high) and therefore more protected.
Sports Stadium, Arena & Race Track	Sport & recreation (high intensity)	65	65	
Public Assembly	Community hall, library etc.	65	70	
Cemeteries/Crematoria	Cemetery	75	75	
Personal Services	Offices	65	75	

Table A.3 Noise sensitivity classification of zoning categories

ZONING CATEGORY	CORRESPONDING LAND USE TYPE IN COMPATIBILITY TABLE	CONSERVATIVE OPTION (max in DNL)	LIBERAL OPTION (max in DNL)
Amenity	Community hall	65	70
Business 1/Local/Minor/Special Business (low intensity)	Retail (low intensity)	70	75
Business 2/General business/Commercial (med intensity)	Retail (high intensity)	65	70
Business 3/Central business (high intensity)	Retail (high intensity)	65	70
Business 4/Service station	Public garage	75	75
Business 5 (Buffer between high & medium intensity)	Retail (high intensity)	65	70
Cemetery	Cemetery	75	75
Civic and Community	Community hall	65	70
Institutional (Community Facility)	Community hall	65	70
Institutional (Place of Instruction)	Educational	60	65
Educational	Educational	60	65
Institutional 1/2/3	Educational	60	65
General industrial (light & risk)	Manufacturing	75	75
Local Authority/Government	Offices	65	75
Municipal Services/Public utility/Substation (Gas & Electricity)	Manufacturing	75	75
Transport 1 (Railway lines, bus depots, taxi ranks)	Bus, municipal & other depots/ Vacant land*	75*	75*
Transport 2 (Roads & streets)	Vacant land	80>	80>
Transport 3 (Parking)	Parking garage	80	80
Open Space 1/2/Public/Private	Picnic facilities	75	75
Residential 1/Single (low density)	Low density residential	65	65
Residential 2/Informal (high density)	High density residential	55	60
Residential 3/Special (medium density)	Medium density residential	60	60
Residential 4/General (high density)	High density residential	55	60
Rural (agriculture)	Agriculture-cattle farming*	75*	75*

**chose most protected one in each classification*